Identification of Soiling Properties for Different Minerals on Solar Mirrors via Artificial Soiling Setup

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Dr. Florian Wiesinger
Dr. Florian Sutter
Dr. Aránzazu Fernández-García
Dr. Fabian Wolfertstetter

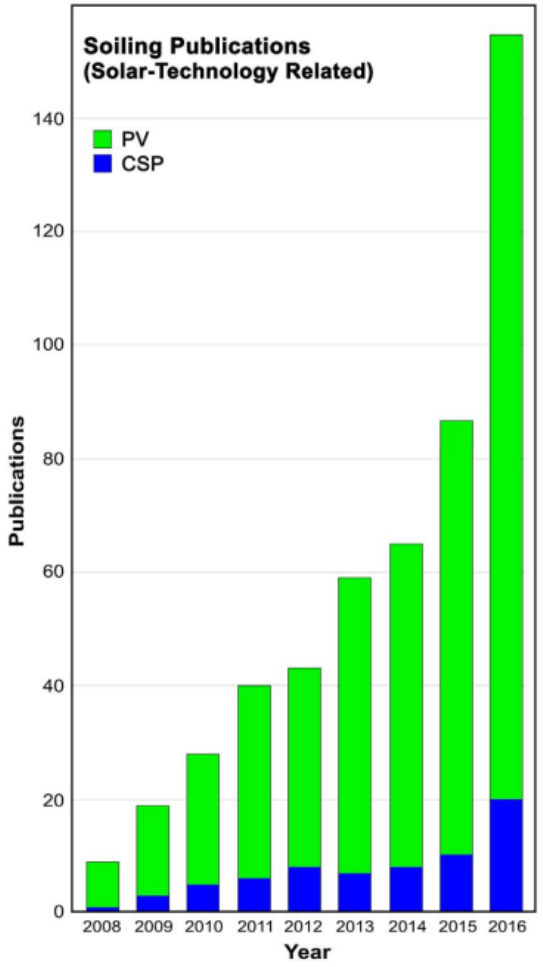
Overview

- Introduction
  - Motivation, economical and environmental cost of soiling
- Methodology
  - Artificial soiling setup
  - Optical measurement systems
- Results
  - Homogeneity
  - Reflectance after cleaning
  - Comparison to outdoor samples

Aïssa 2016

Motivation

- Solar industry progressively targets arid areas for their projects.
- Increasing economic loss of 3-5 billion €.
- Water is a scarce resource especially in arid areas.
- In order to assess mitigation techniques and qualify novel materials accelerated soiling tests are inevitable.
- Types of dust vary significantly for different sites.



Costa 2017
Ilse 2019

Motivation – soiling characteristics

- Diameter of particles between submicron to around 50µm.
- Mineralogical composition and morphology varies around the globe (calcite, dolomite, quartz, feldspars and gypsum).
- Mineralogy determines chemical and morphological characteristics.
- Also dew and rain are an additional parameter.

	Na_2O	K_2O	MgO	Al_2O_3	SiO_2	CaO	Fe_2O_3	TiO_2	SO_2
Erg Chebbi	0.89	0.94	0.74	0.86	36.64	59.92			
Tabernas	1.15	3.74	0.93	17.22	65.95	2.04	7.38	1.12	
Tantan		1.48	4.57	5.65	30.86	53.35	4.07		
Zagora	1.14	3.12	1.23	7.89	72.87	7.65	4.35		1.38
Erfoud		1.3	0.98	2.7	59.35	32.89	2.73		
Ben Guerir	1.71	2.18	1.72	9.29	38.85	38.16	5.16		2.53
Missour	0.64	0.88	0.81	3.81	12.88	66.5			14.62

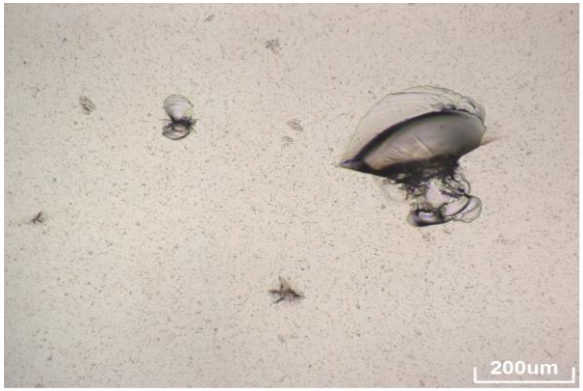
https://www.sand.world/sand-collection/index

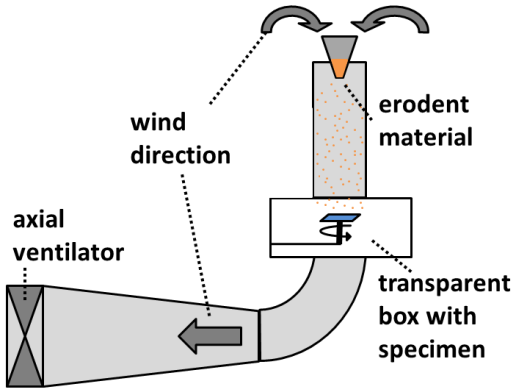
Motivation – mineralogy on erosion

Different minerals also influence erosion intensity:

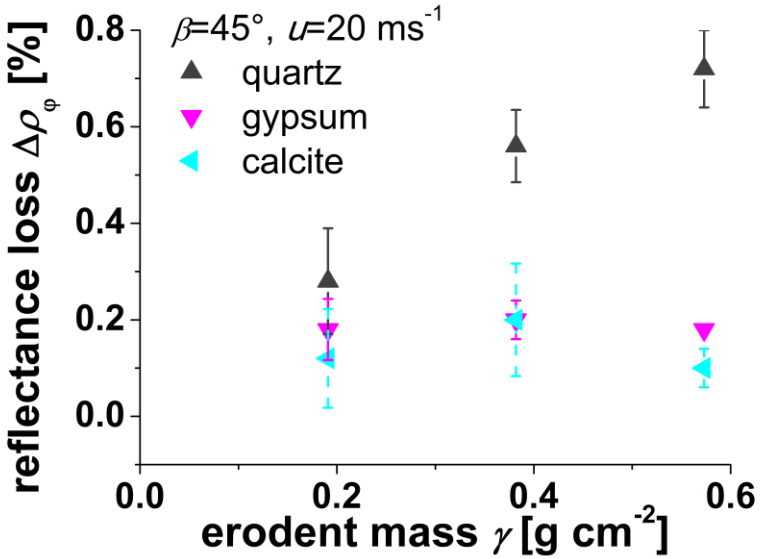
Glass mirrors exposed in artificial erosion setup to three different mineral test dusts (quartz, gypsum and calcite)

→ Quartz highest effect on erosion, ascribed to highest mineral hardness.



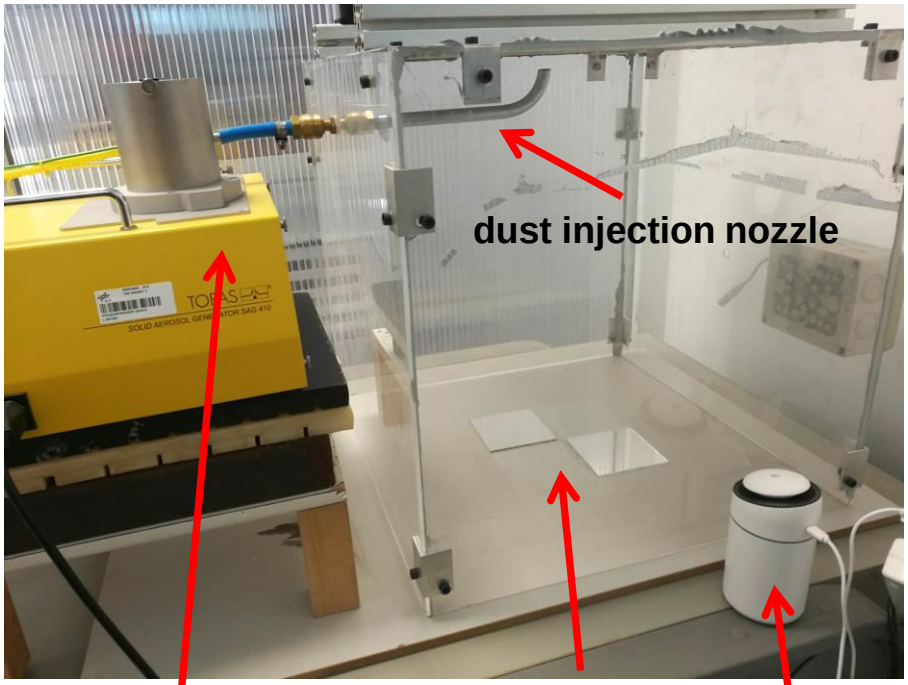


Setup sketch



Wiesinger 2018

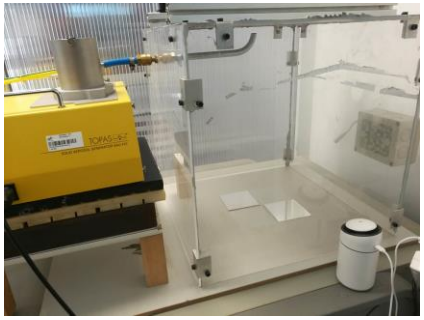
Methodology – artificial soiling setup



Setup Characteristics:

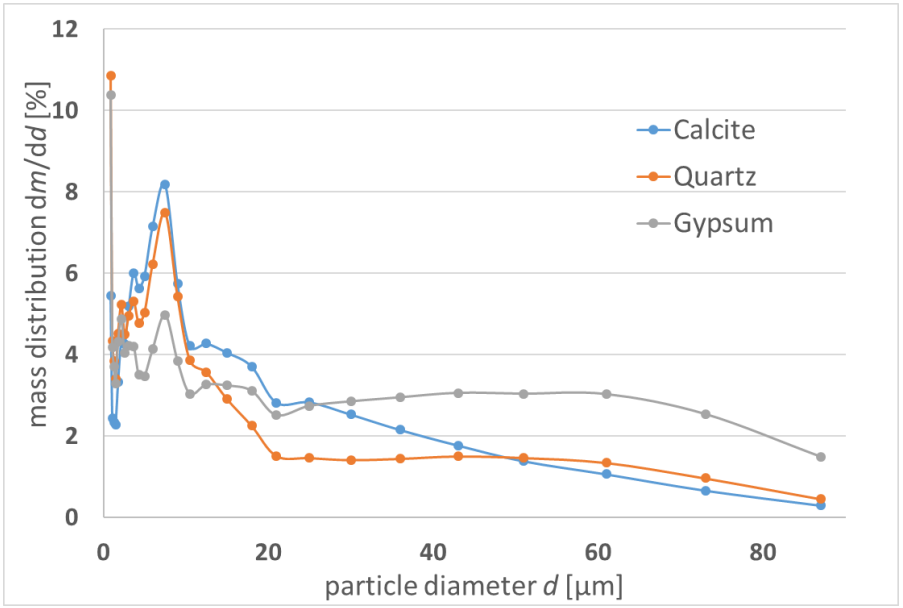
- Constant and continuous dosing also at small mass flow rates down to 0.2g/h
- Usage of different powders possible.
- Nebulizer produces fine water mist to simulate dew formation.

Methodology – Test dusts



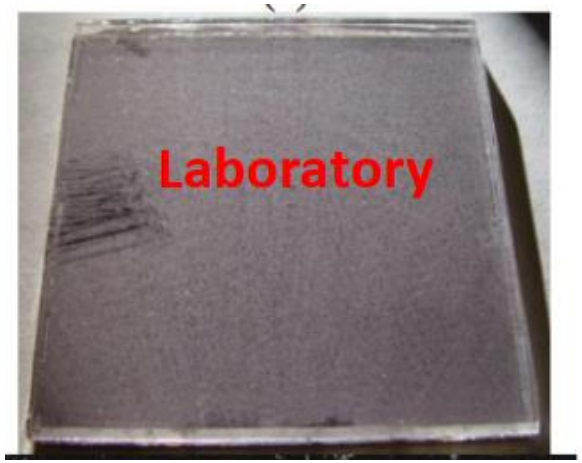
Test dusts:

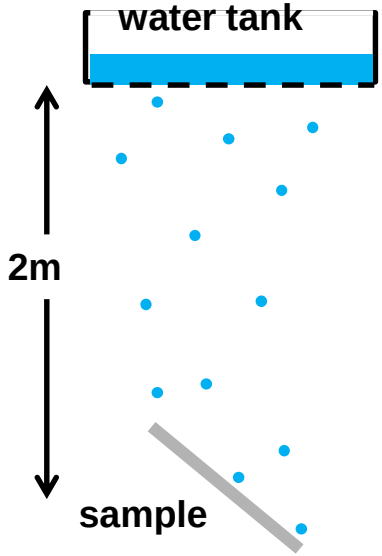
- Calcite
- Quartz
- Gypsum
- PSA (Spain) <53µm



	Na_2O	K_2O	MgO	Al_2O_3	SiO_2	CaO	Fe_2O_3	TiO_2	SO_2
PSA (Spain)	1.15	3.74	0.93	17.22	65.95	2.04	7.38	1.12	

Methodology – soiling procedure





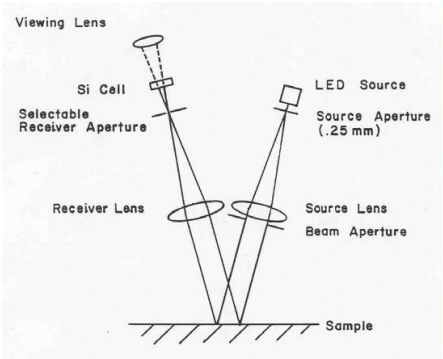
Soiling Issue: Inhomogeneous soiling characteristics from outdoor samples

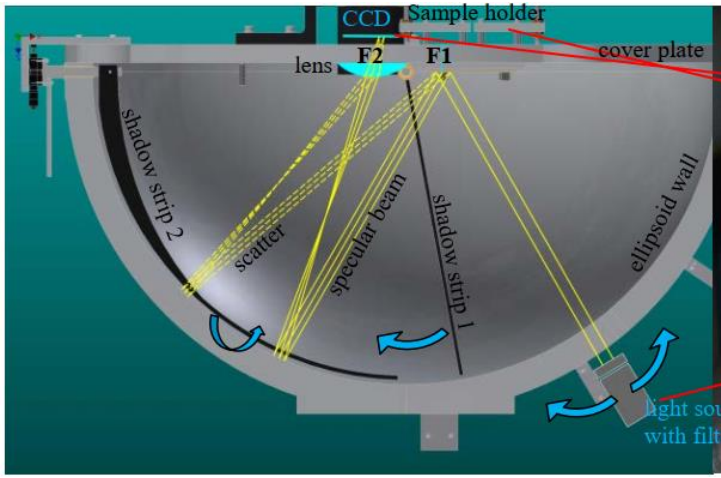
Procedure: soiling → water vapor → characterization → **artificial rain** → characterization

Artificial rain specificiations: Around 4l/m² raindrops from 2 meters height, airdry afterwards.

Heimsath 2019

Methodology – characterization





Devices & Services –Reflectometer Model 15R-RGB:

- Acceptance angles φ= 7.5, 12.5, 23 mrad
- Wavelength of light source: λ= 660nm
- Incidence angle θ =15°

Goniophotometer (MIRA):

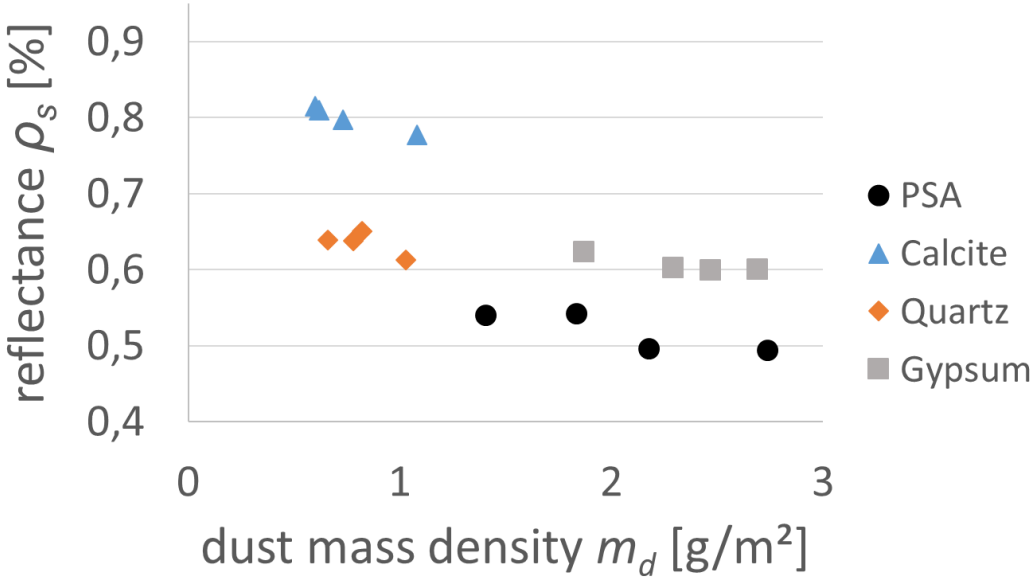
- Acceptance angles φ up to 100mrad
- Wavelength of light source: λ= 633nm
- Incidence angle θ=7- 45° (set to 15°)

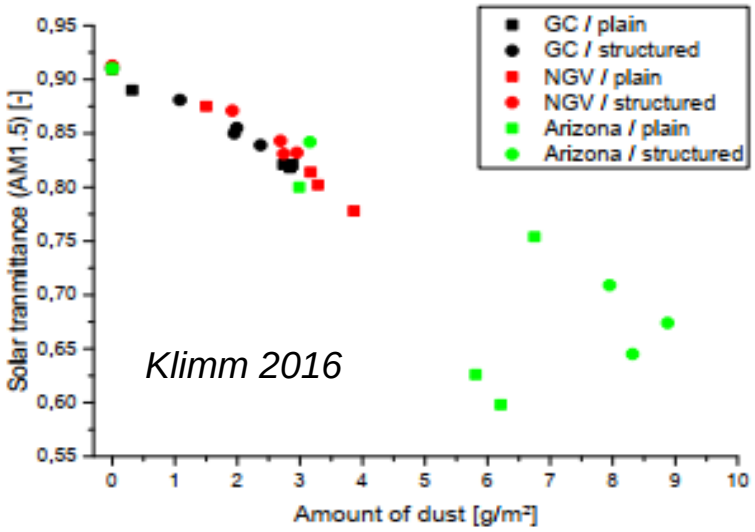
Meyen 2014

Results – Calibration: mass to reflectance

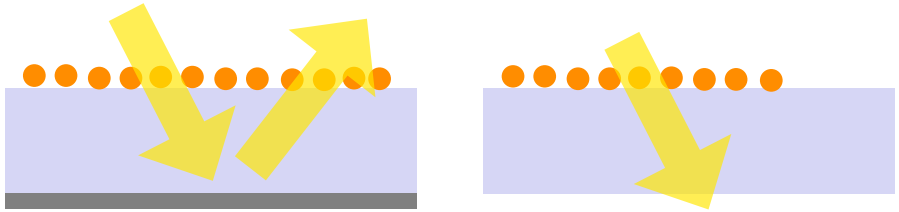
Dust mass m_d on reflector in relation to reflectance loss ρ_s.

- With increasing m_d lower ρ_s
- Different characteristics for every mineral.
- Similar order of magnitude like *Klimm et al.* – !Reflectance loss and transmittance loss!



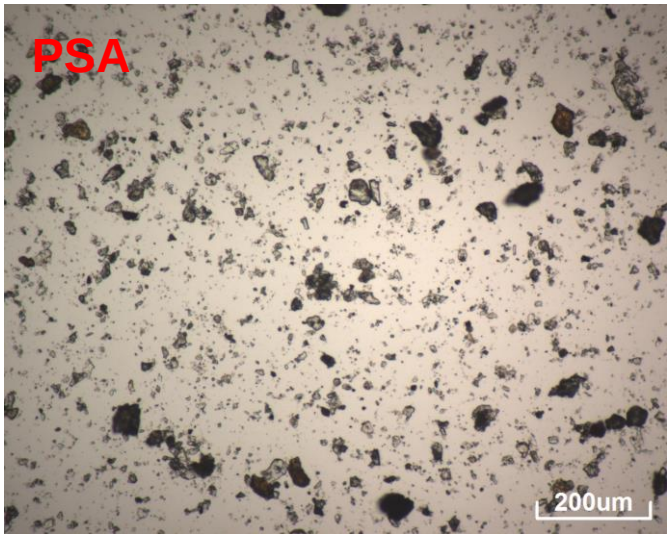


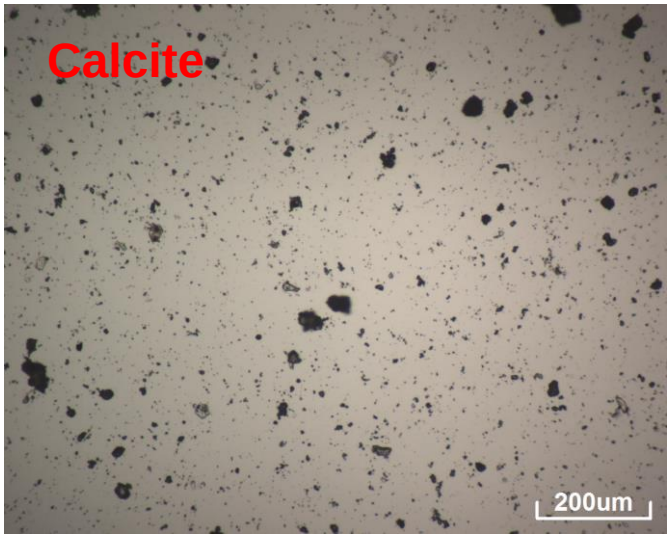
Klimm 2016

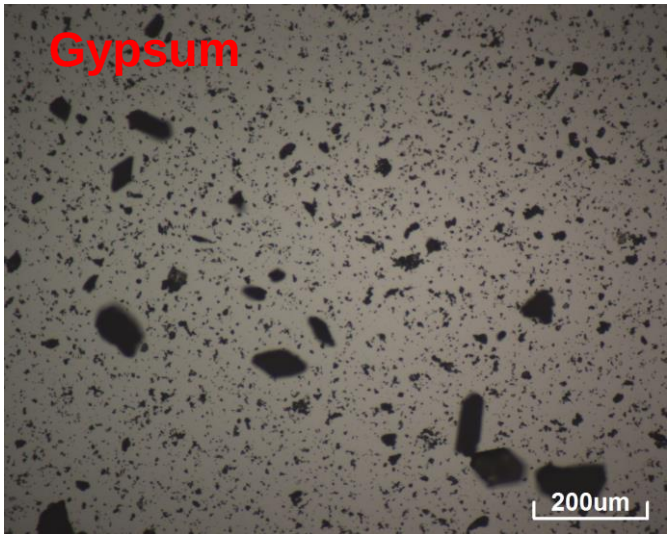


Reflectance: light needs to pass soiled layer twice, transmittance only once.

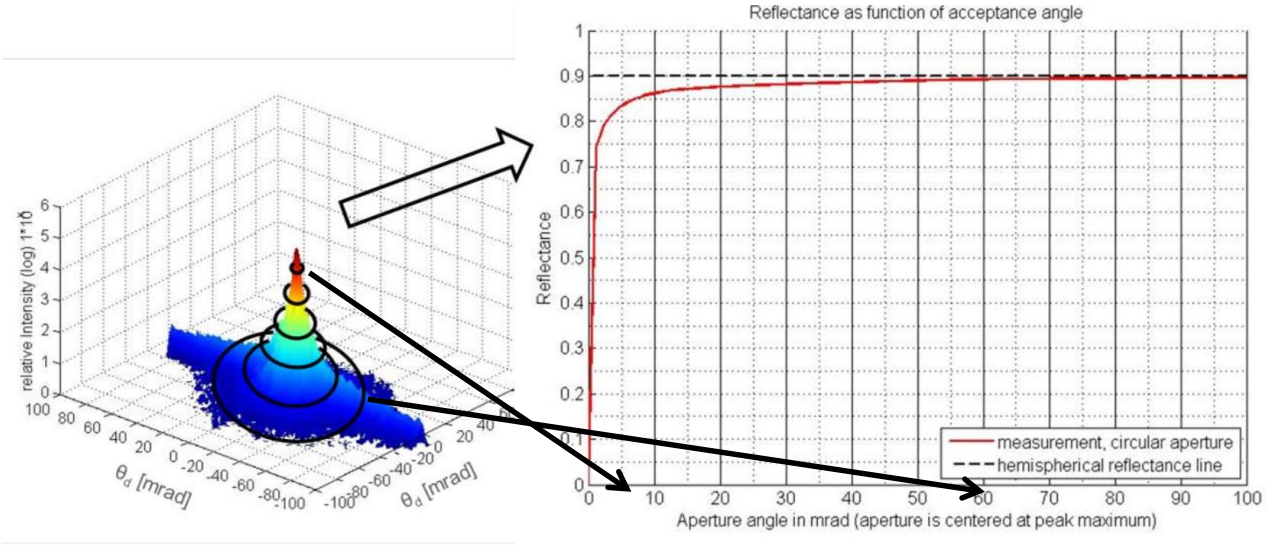
Results – microscope after soiling procedure



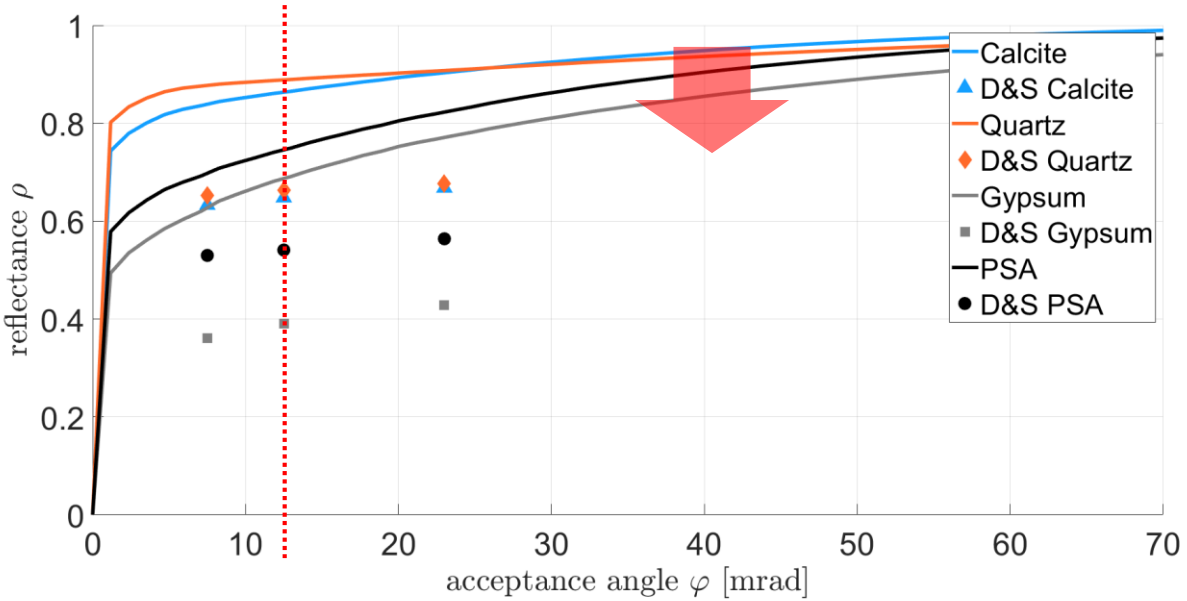




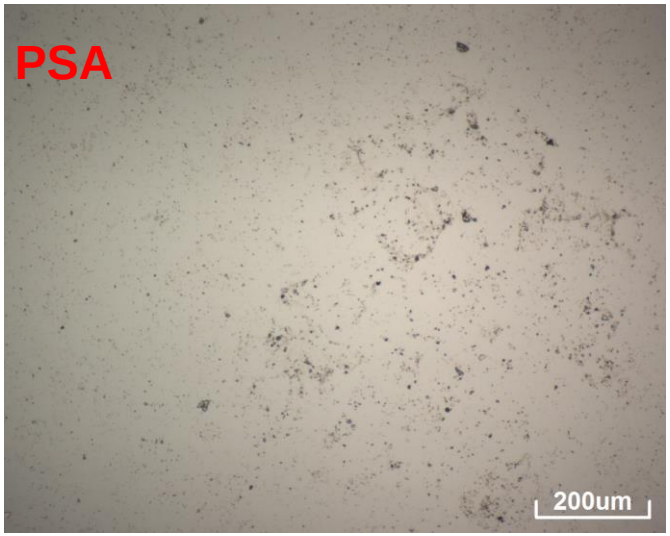
Results – reflectance data from MIRA and D&S

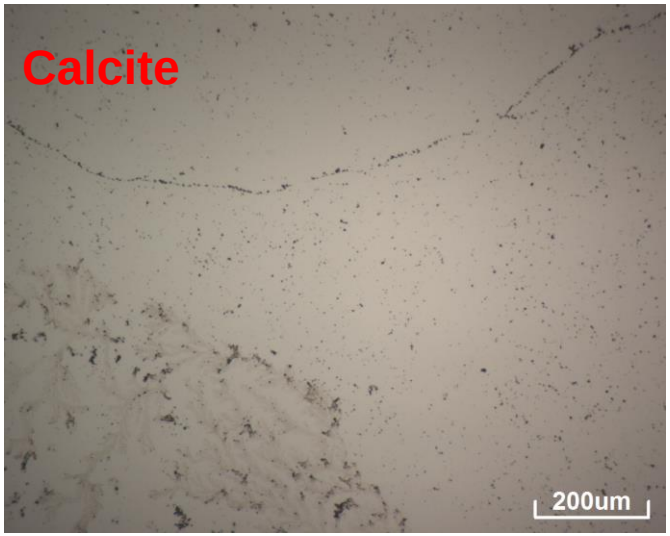


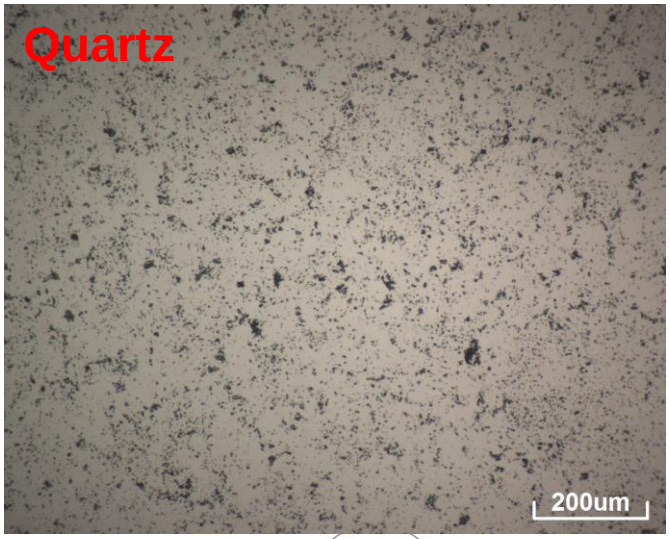
- Dots represent D&S measurement.
- Issue: not calibrated to hemispherical reflectance
- Dust on the surface leads to increased scattering of reflectors.

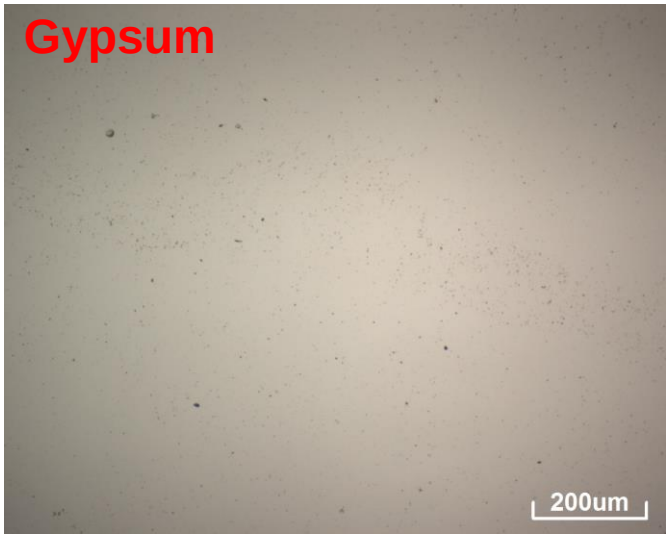


Results – after cleaning by artificial rain

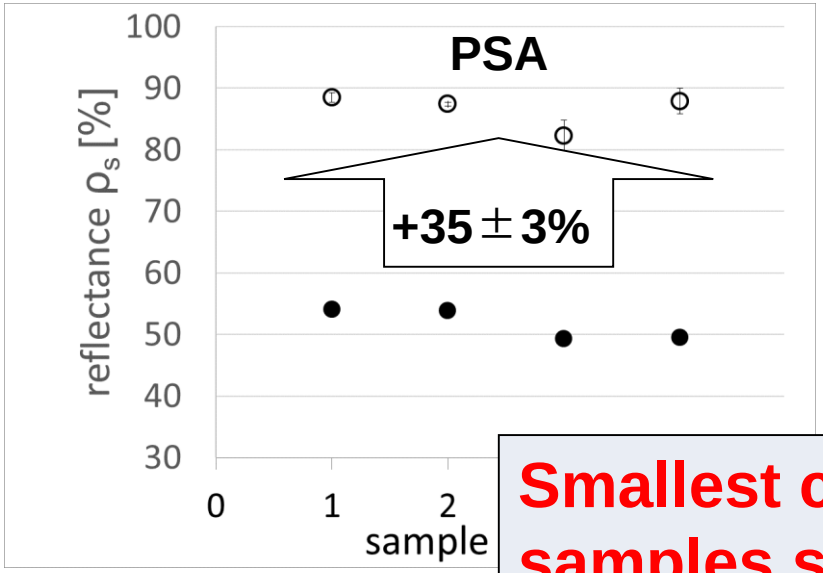


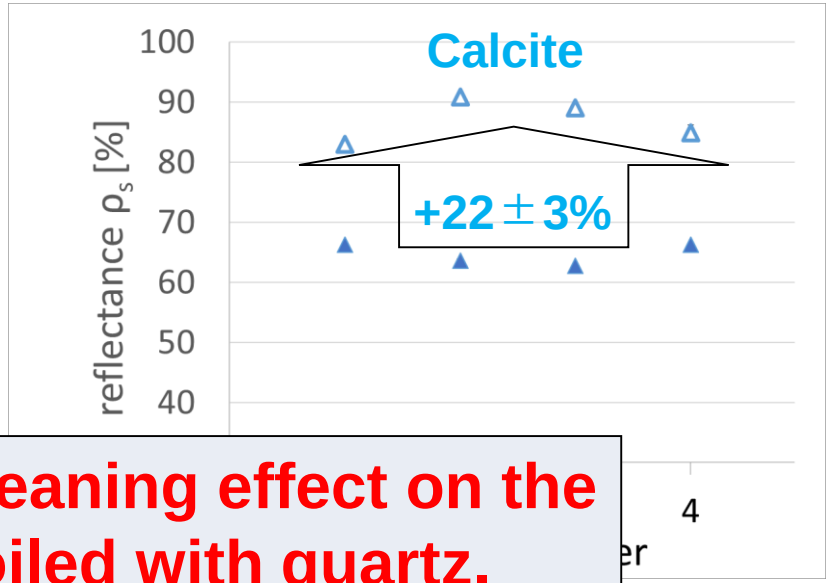




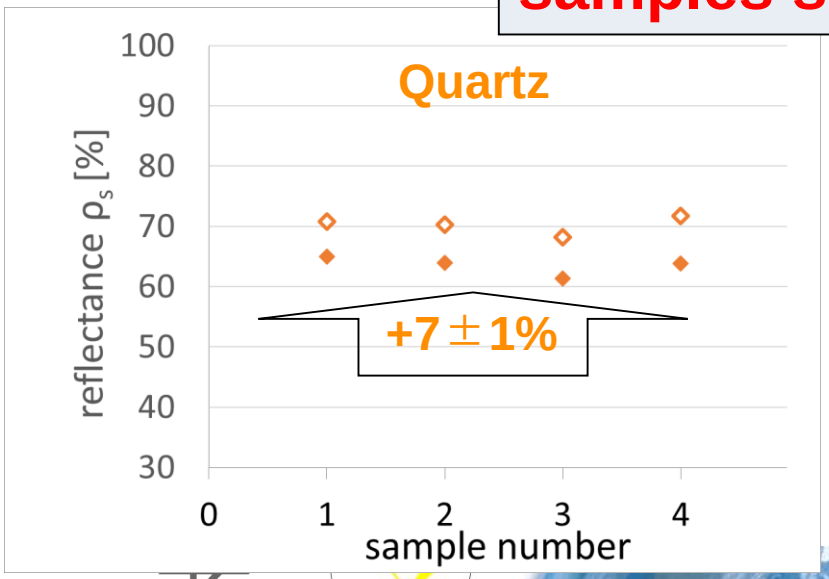


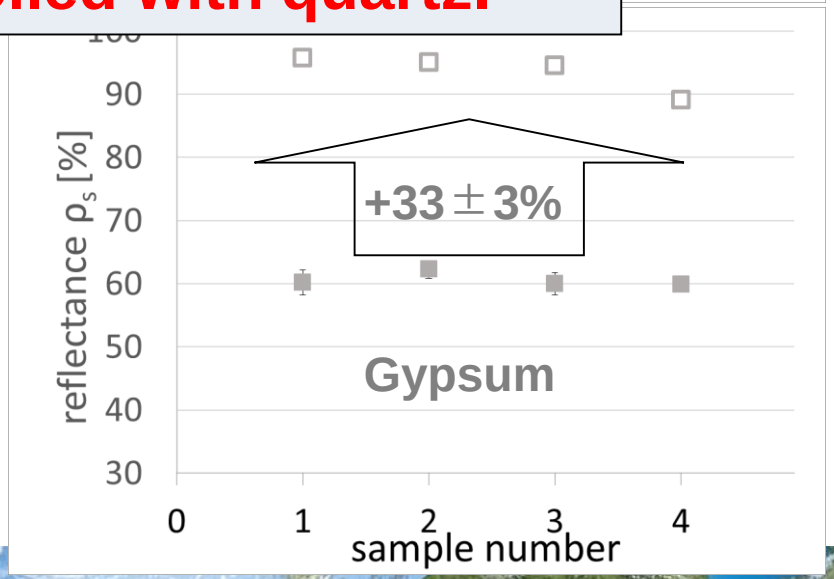
Results – reflectance data after rain



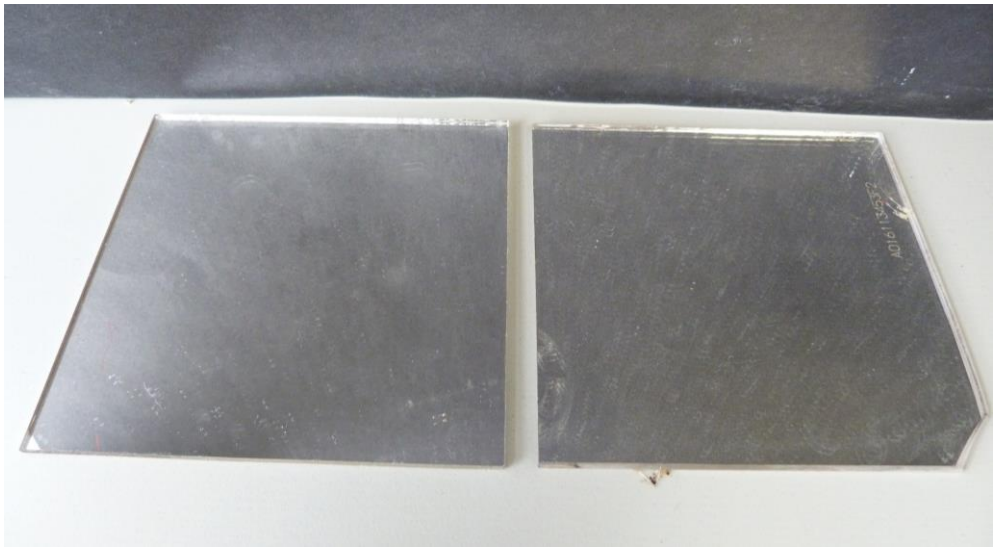


Smallest cleaning effect on the samples soiled with quartz.

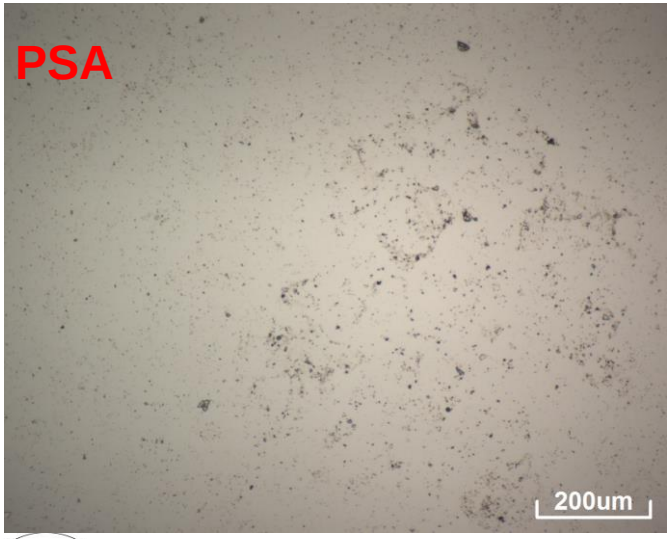




Results – comparison to real outdoor sample from PSA



→ Comparable soiling picture from artificial laboratory experiment and outdoor exposure



Conclusion and Outlook

- An artificial soiling setup has been developed, promising first test results regarding, homogeneity, reproducibility and realistic properties.
- Different test dusts could be applied on state of the art reflector samples.
- Reflectance in the soiled state was comparable for all samples.
- An artificial rain cleaning procedure could restore the initial reflectance partially.
- The cleaning procedure had the smallest effect for the sample soiled with quartz dust.

- Search for further characterization techniques in order to describe similarity between real outdoor and artificially soiled samples.
- Round Robin Partners

Bibliography

- Costa, Diniz, und Kazmerski, „Solar Energy Dust and Soiling R&D Progress“.
- Pescheux, Le Baron, und Raccurt, „Characterization of different Moroccan sands to explain their potential negative impacts on CSP solar mirrors“.
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- Heimsath und Nitz, „The effect of soiling on the reflectance of solar reflector materials - Model for prediction of incidence angle dependent reflectance and attenuation due to dust deposition“.
- Klimm u. a., „Microscopic Measurement and Analysis of the Soiling Behavior of Surfaces with Standardized and Real Dust – A Parameter Study“.

Thank you for your attention

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Florian.Wiesinger@dlr.de