Karlsruher Institut für Technologie

Soiling Measurements in Photovoltaic Applications and Concentrated Solar Power Plants

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Overview

- Motivation

  PerduS – Project

  - Karlsruhe Institute of Technology (KIT)
  - Deutscher Wetterdienst (DWD)
  - Meteocontrol
- Measurements, Solar modules + more

  - Karlsruhe Institute of Technology (KIT)
- Results
- Concentrated Solar Power Plants

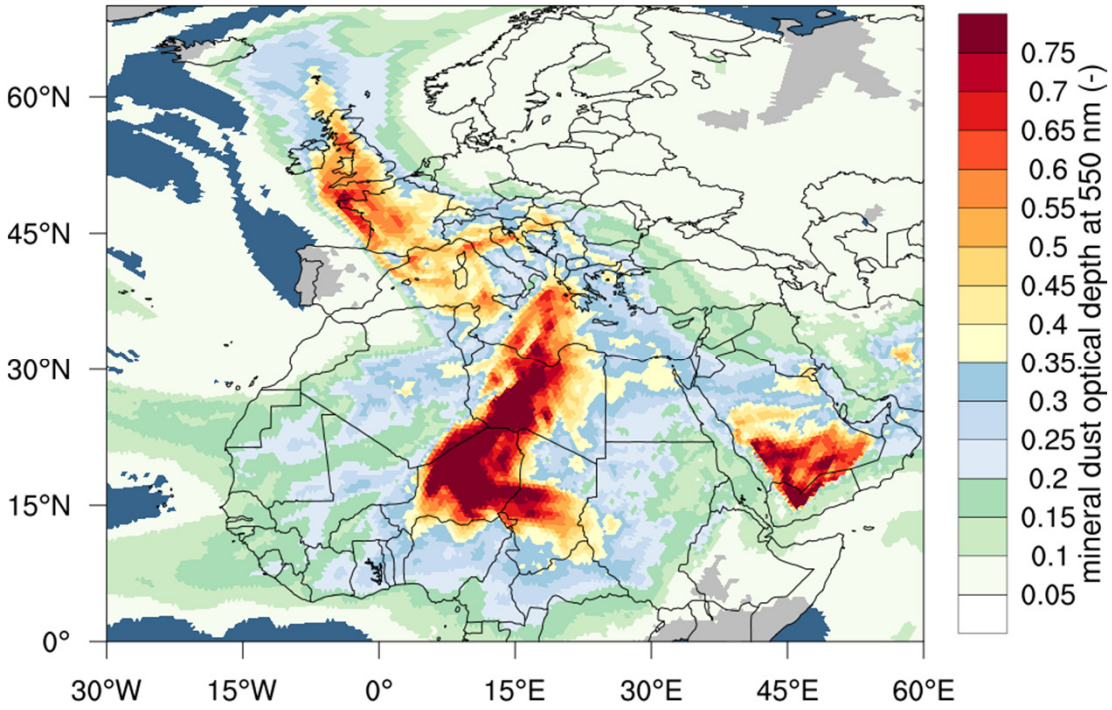
  - Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
- Concluding Remarks

Project PerduS

- Forecast of PV Energy Reduction due to desert dust
  - Direct atmospheric effect (AOD of dust particles)
  - Indirect atmospheric effect (cloud modification)
  - Soiling effect

- Example:

  2019_04_23 12:00



Bundesministerium für Wirtschaft und Energie

Projektträger Jülich Forschungszentrum Jülich

MEASUREMENT SITE

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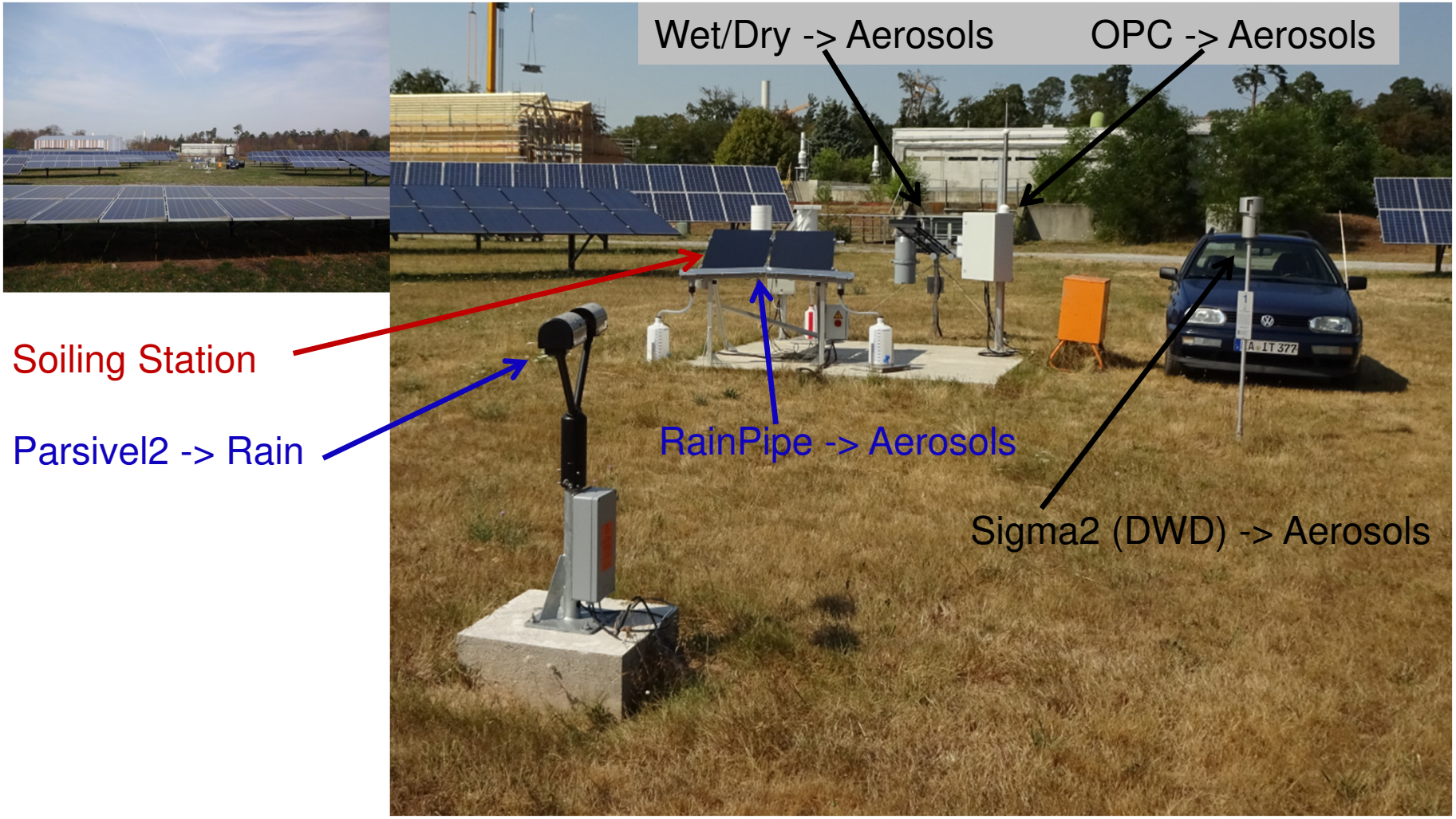
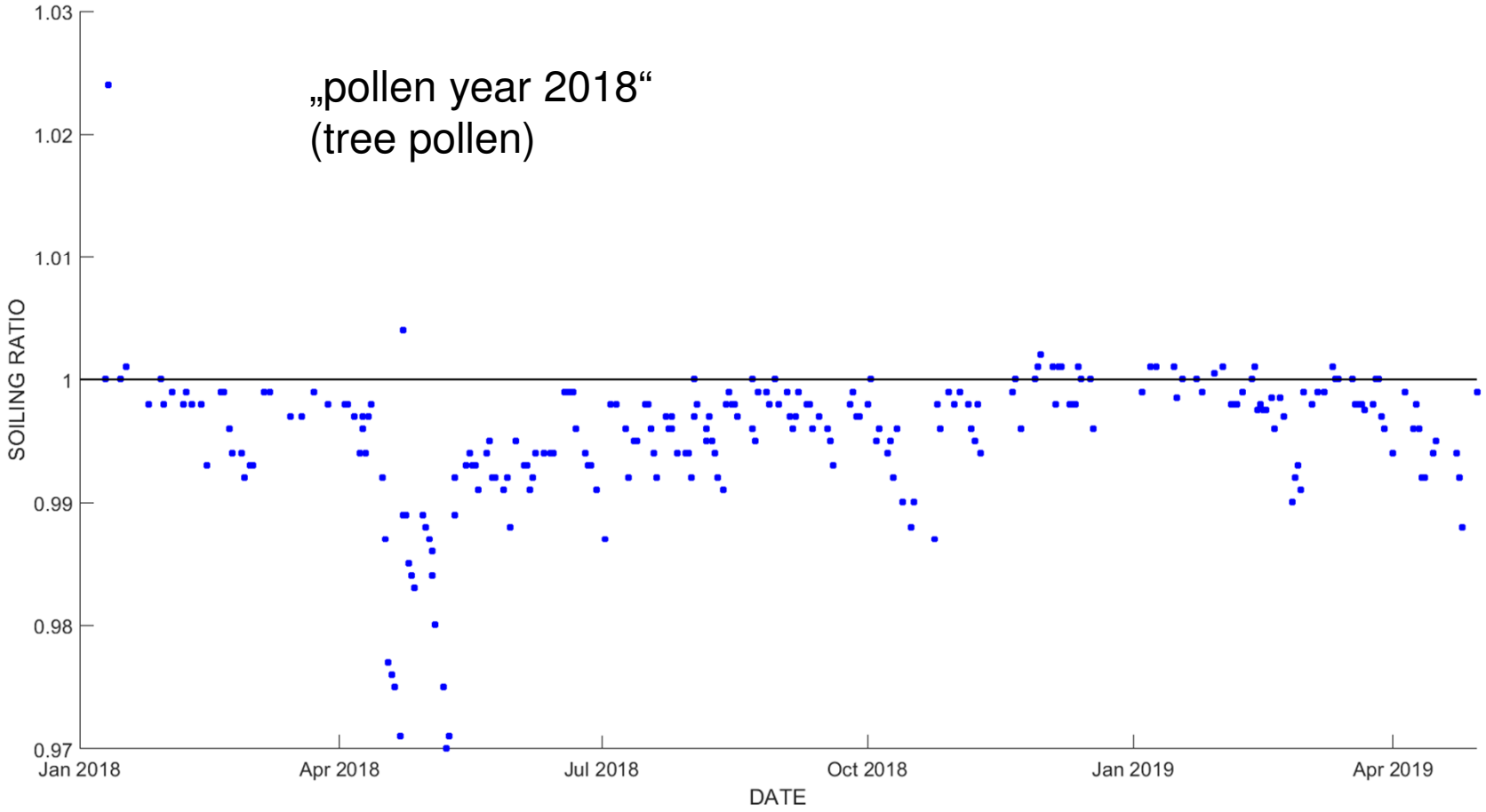


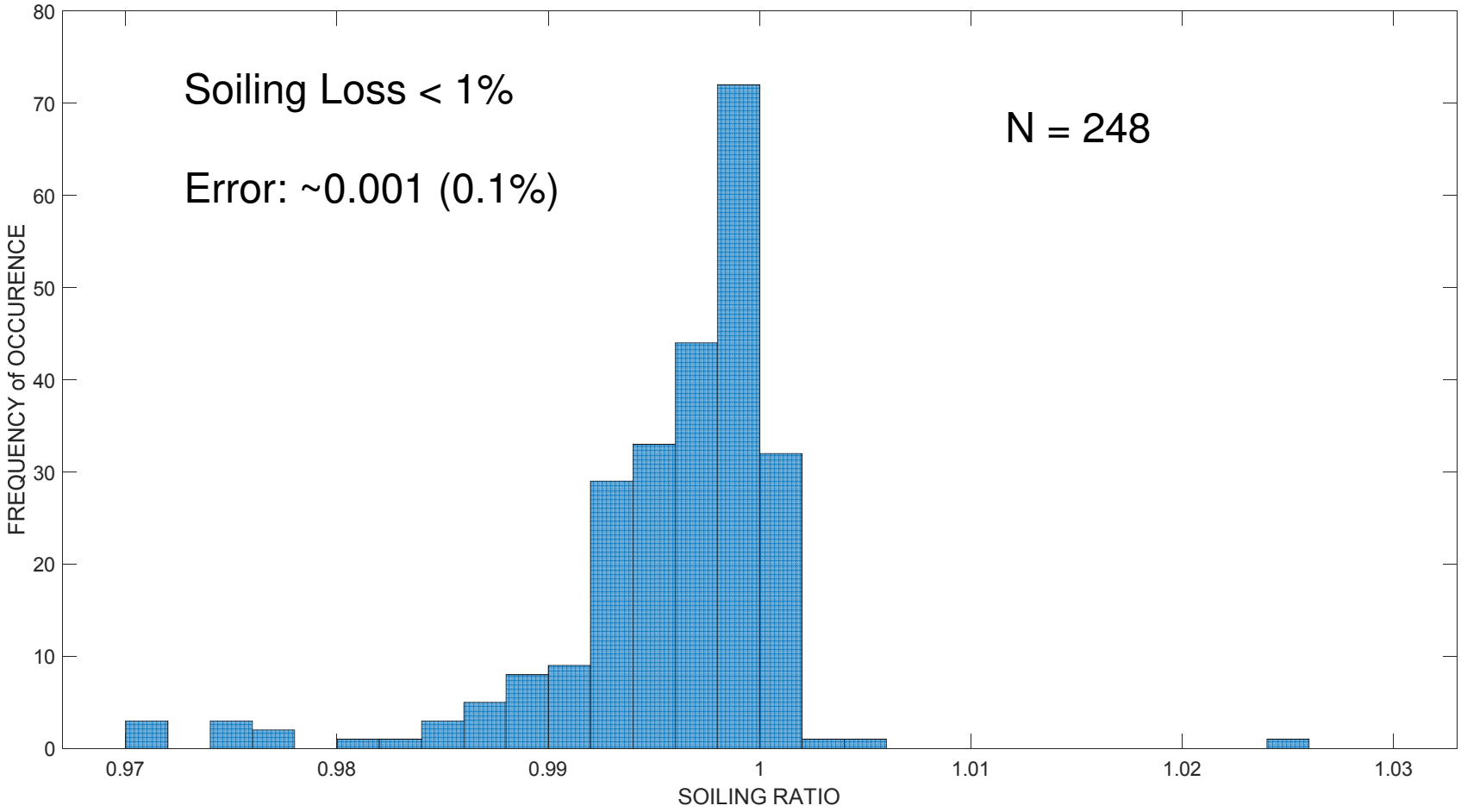
Time Series of Soiling Ratio



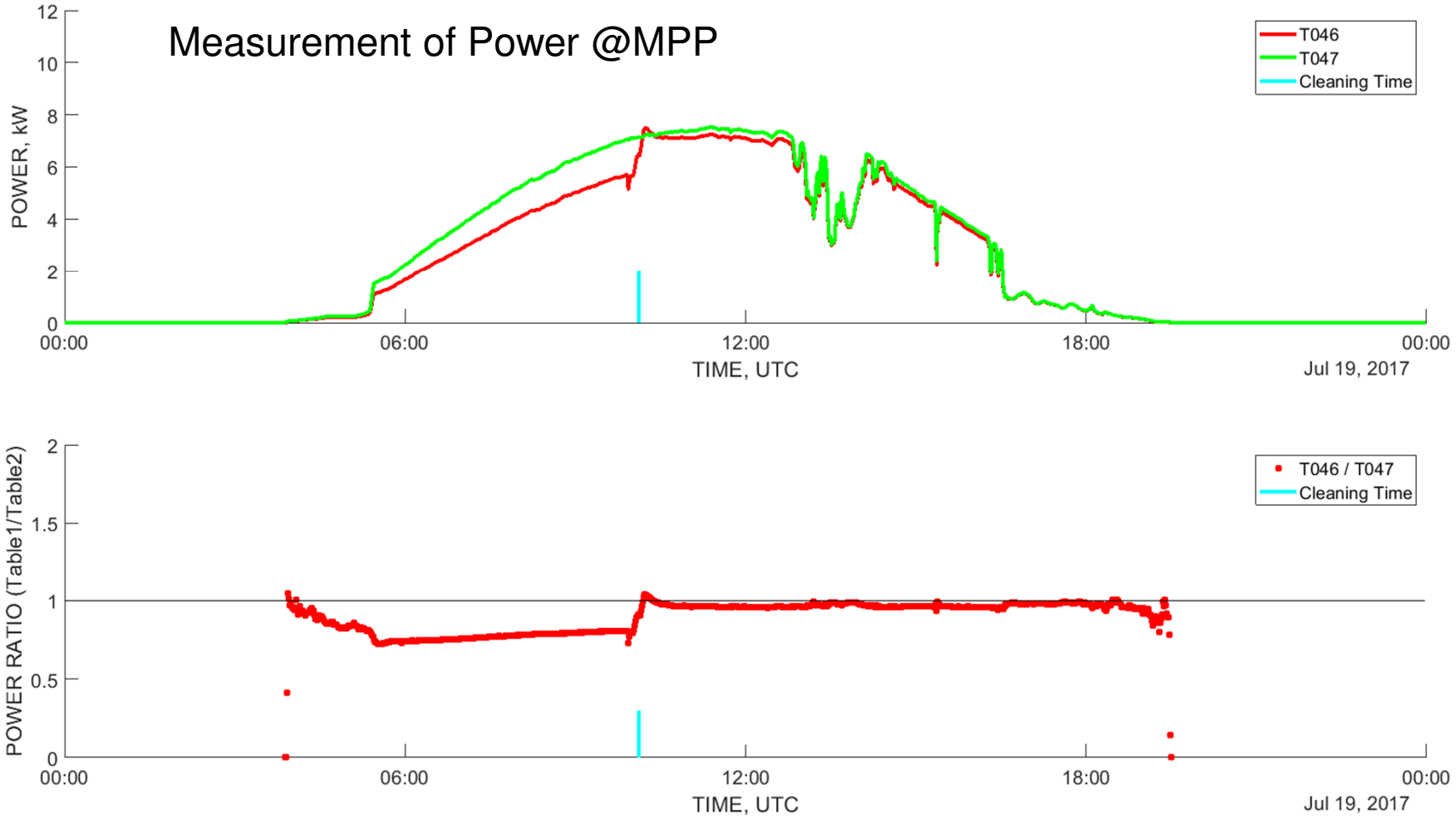
SOILING RATIO: Histogram

$$SR = \frac{Rad(soiled)}{Rad(ref = cleaned)}$$

Measurement of I_{SC}

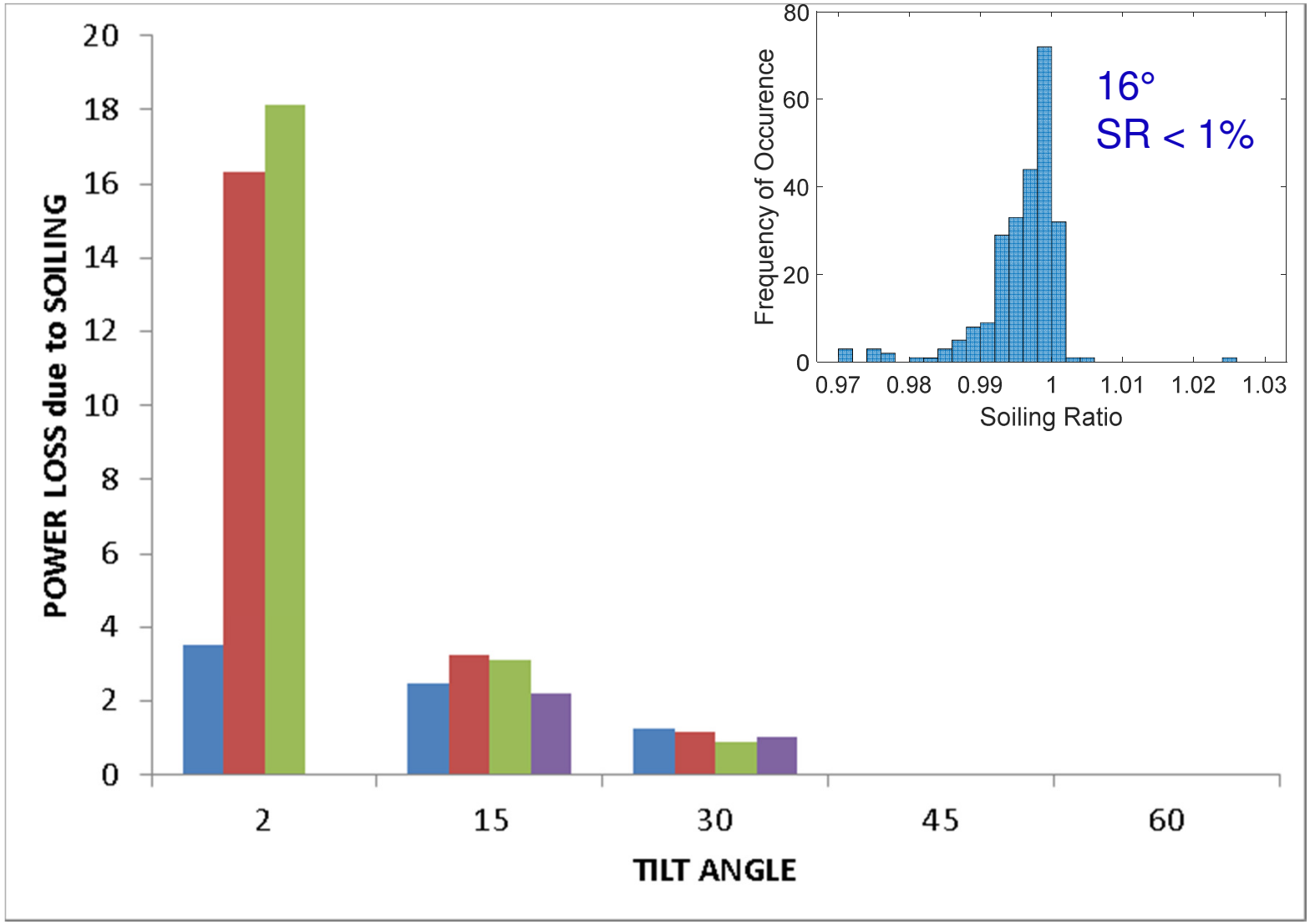


Analysis of 2-years soiling: method, 2° tilt

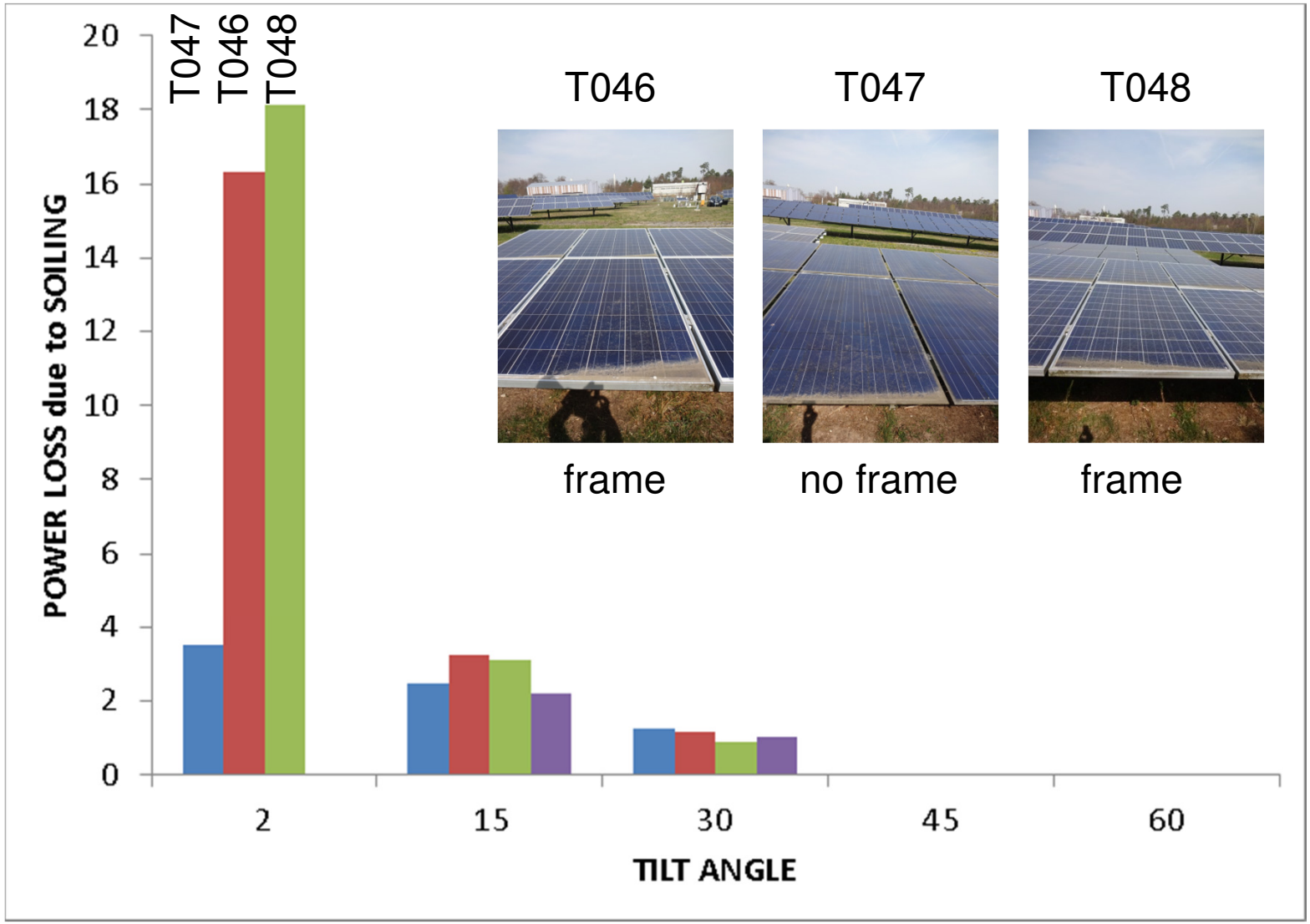


Power data were provided by Batterietechnikum at KIT.

RESULTS

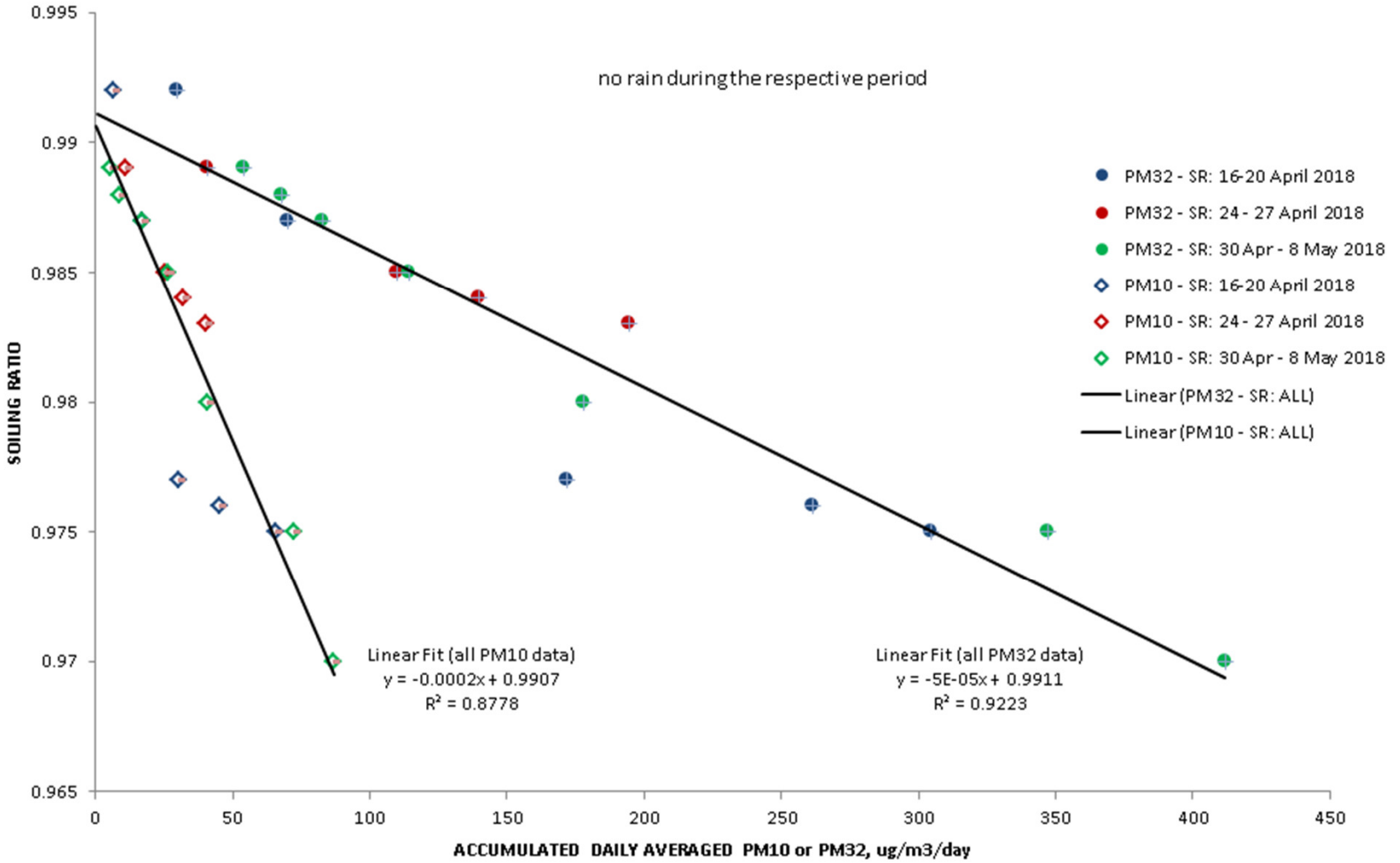

POWER LOSS due to SOILING
20
18
16
14
12
10
8
6
4
2
0
2
15
30
45
60
TILT ANGLE
Frequency of Occurence
80
60
40
20
0
0.97
0.98
0.99
1
1.01
1.02
1.03
Soiling Ratio
16°
SR < 1%

RESULTS

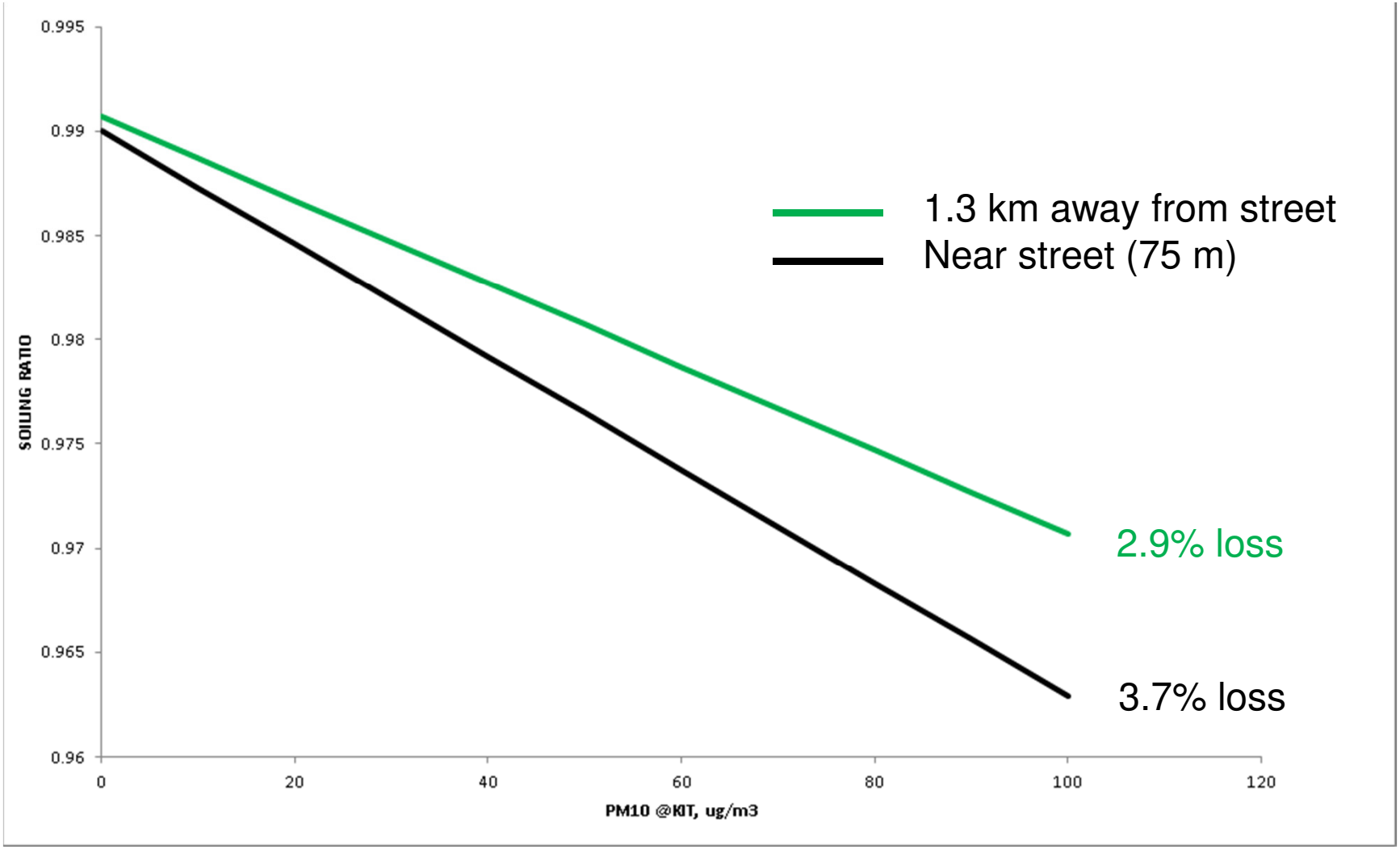

T047
T046
T048
20
18
16
14
12
10
8
6
4
2
0
POWER LOSS due to SOILING
2
15
30
45
60
TILT ANGLE
T046
T047
T048
frame
no frame
frame

SOILING RATIO and PM MASS CONC.

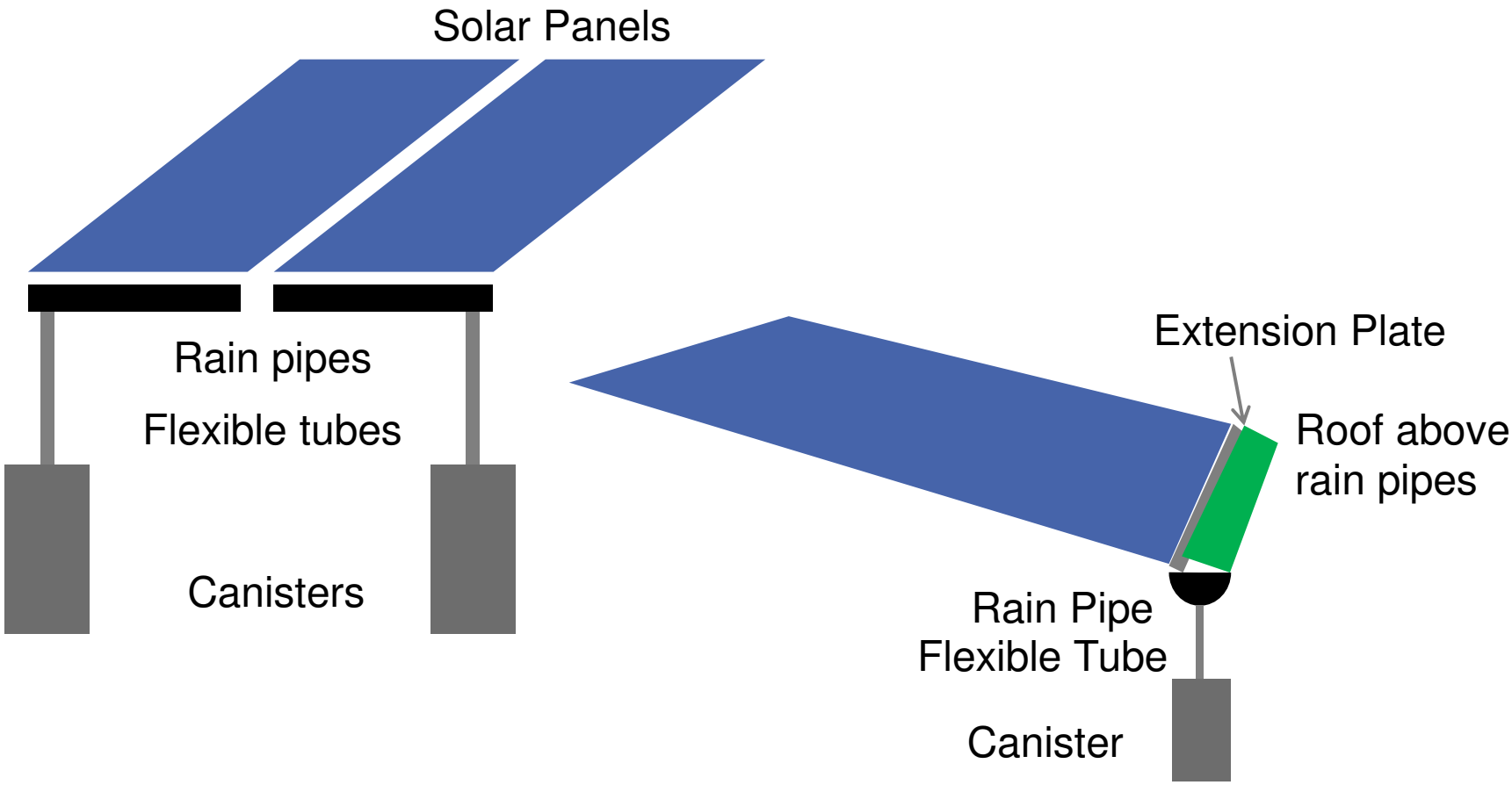
(last year‘s pollen episodes)



PM10 mass concentration -> SoilingRatio



Rain Pipe Collection System

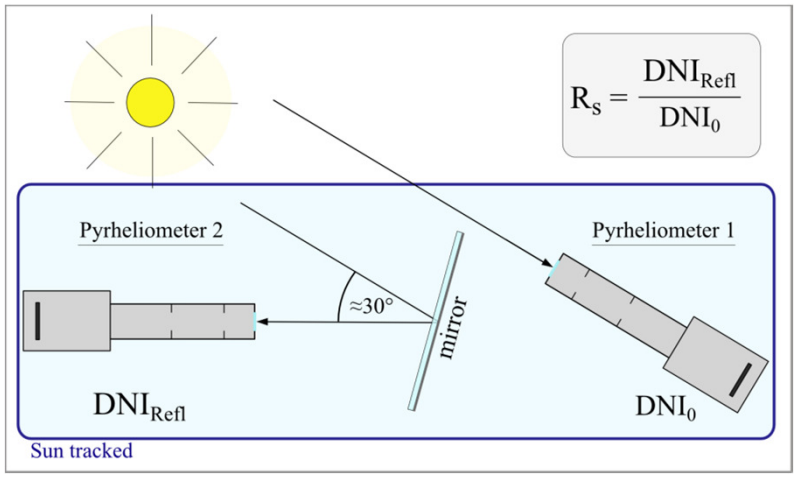


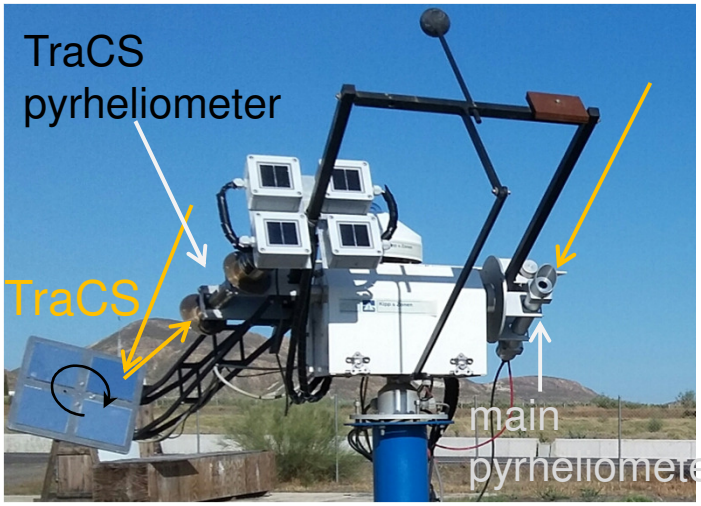
Capabilities of Rain Pipe Collection System

- Collection of dust from solar panels
  - Collection of dust by human cleaning
  - Automatic collection of dust by natural events
    - Rain
    - Very little drizzle (not recorded by tipping bucket rain gauge but by parcivel2)
    - Dew
    - Frost pattern (after melting)
    - (Snow) - not in current installation
- Water amount collected from panel agrees well with meteo measur.
  $\Rightarrow$ Quality check
- Dew => 30-200ml
- Frost pattern => 60-90 ml

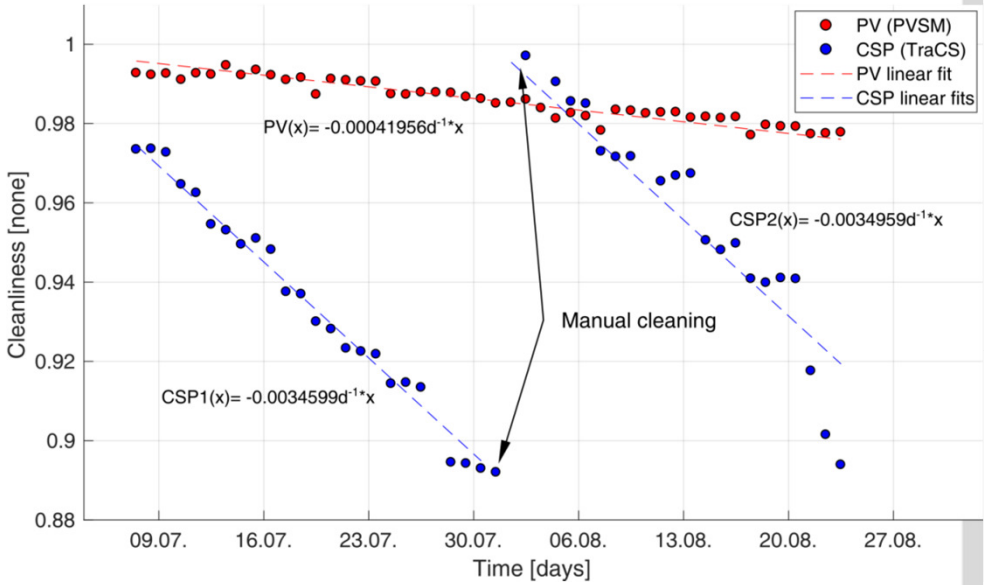
Measurement of Soiling of CSP mirrors

Tracking **C**leanliness **S**ensor - TraCS





- Solar weighted <u>specular reflectance</u>
  $\rho = DNI_{mirr} / DNI_{sun}$
- Cleanliness = $\rho_{soiled} / \rho_{clean}$
- TraCS [1]:
  - Parallel real time measurement of 4 mirror samples
  - Sun as light source
  - Rotation to increase measurement spot
- Handheld or lab devices available [2]



[1] Wolfertstetter, F. et al. (2012). A novel method for automatic real-time monitoring of mirror soiling rates. SolarPACES 2012.
[2] Fernández-García, A. et al. "Equipment and methods for measuring reflectance of concentrating solar reflector materials." Solar Energy Materials and Solar Cells 167 (2017)

Concluding Remarks

Soiling Ratio in Germany is low 1-3%

Rain does a good job in cleaning

CSP are more sensitive to soiling

Rain Pipe Collection System developed