

# Soiling Losses in the Atacama Desert

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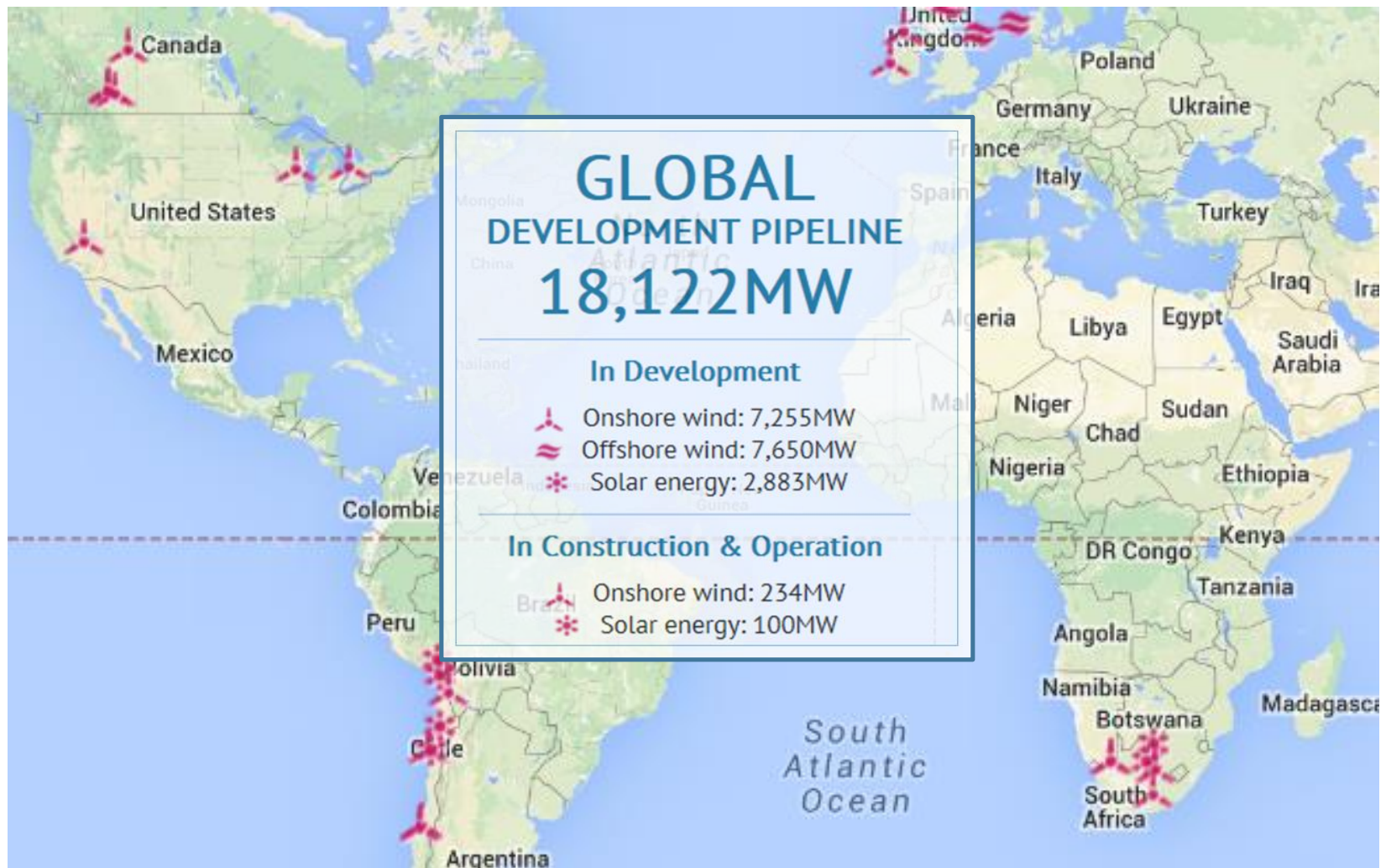
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# Background

What is soiling?

Why are soiling losses relevant to developers, investors and operators?



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# Background – what is soiling?



- Dust, pollen, soot, pollution, bird droppings... unwanted material on panel
- It is very specific to location
- Soiling occurs in all solar parks to a greater or lesser degree
- Panel performance can be severely affected

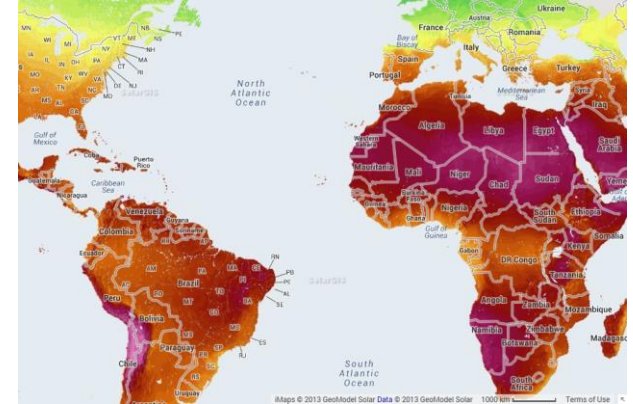
# Why are soiling losses relevant?

## Expert advice (18 months ago)

- What soiling losses can be expected on a dusty and low rain environment?
  - “... between 0 to 40%” (several consultants)
  - Findings from California and MENA are in line with these numbers
- What can be done in the development stages regarding soiling in order to minimise uncertainty??
  - “...choose the right location”
  - “What is important is to state a cleaning procedure in the O&M contract”
  - “Maybe measurements would be useful”
- BUT...
  - How does one choose the right location?
  - Who will take the risk?
  - What measurements are useful?

# The Atacama Desert ~ 128,000 sq km, 1400km long

- Highest irradiation on earth
- Low temperature due to altitude and constant winds
- Some areas have a very good grid connection
- Good energy prices (solar has grid parity without government intervention)
- Low losses? Low uncertainties?
  - Main question mark hangs over soiling.





## A very diverse region: Camanchaca (coastal fog)





## A very diverse region: temperate rainforest



Source <http://www.flickr.com/photos/universidadcatolica/3620747584/>  
Author Pontificia Universidad Católica de Chile

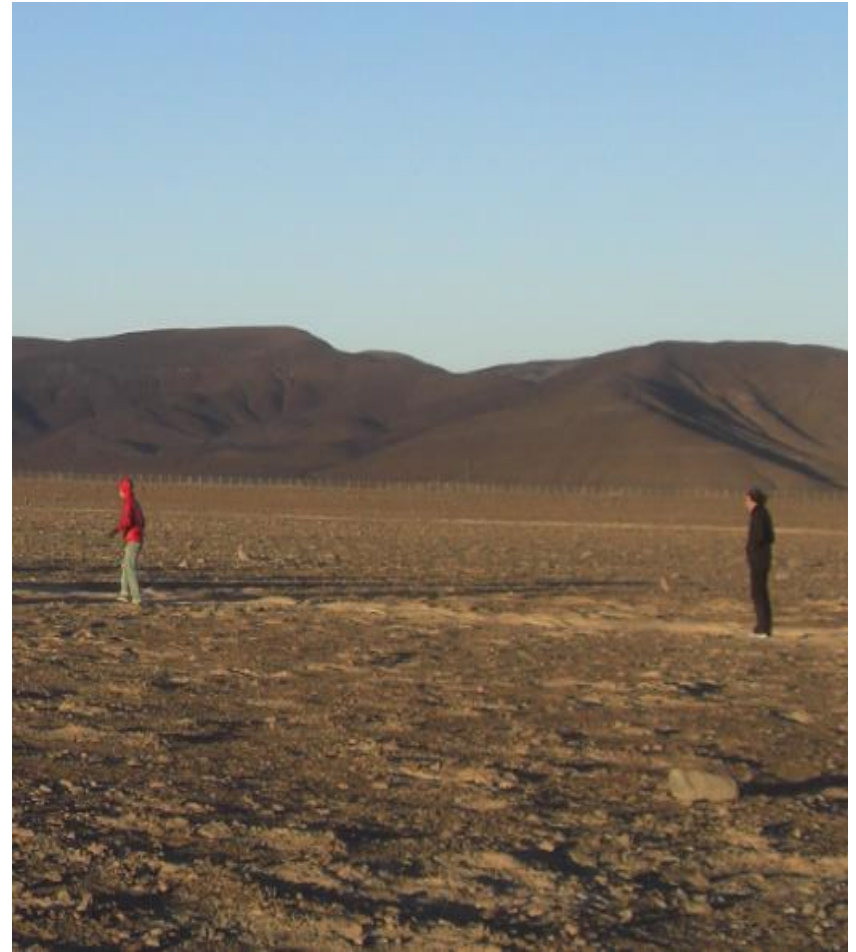
Fray Jorge Forest: just outside southern edge of Atacama



## A very diverse region: mining



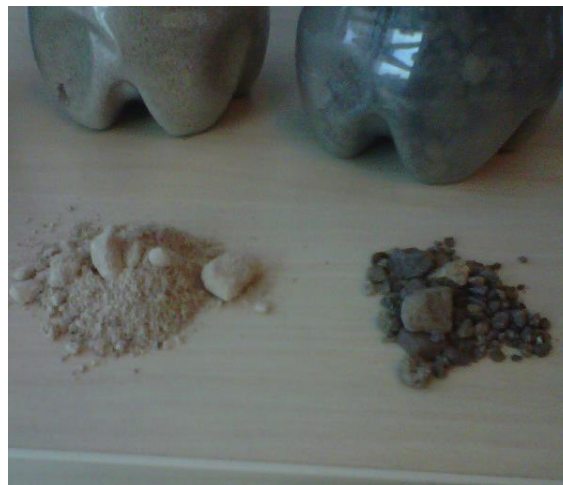
## A very diverse region:



Different soils, volcanoes, salt plains, altitude differences (of up to 6000m), different humidity...



# “Standard” site?



# The Project and the measurements



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# The project and measurement station



- ~800km North of Santiago
- Over 1000m asl
- Up to 140MWac

Measurements since September 2011

- Irradiation
- Wind speed
- Wind direction
- Humidity
- Pressure
- Temperature

But how do we measure soiling?



# The soiling station (prototype 1)



# The soiling station – data collection and routine

## MODULE CLEANING

- Module 1: 3 times a week (dry)
- Module 2: once a month
- Module 3: every 4 months  
(3 cleans/yr as per suggested O&M)
- Module 4: Never



- Module 1: 3 times a week (dry)
- Module 2: 3 times a week (wet)
- Module 3: coated  
(but never cleaned)
- Module 4: Never

## DATA COLLECTION

- Averaged short circuit current ( $I_{sc}$ ) every 10mins
- Photos (3 times a week)
- We compare the performance of the modules 2, 3 and 4 to that of module 1.

# Data Analysis



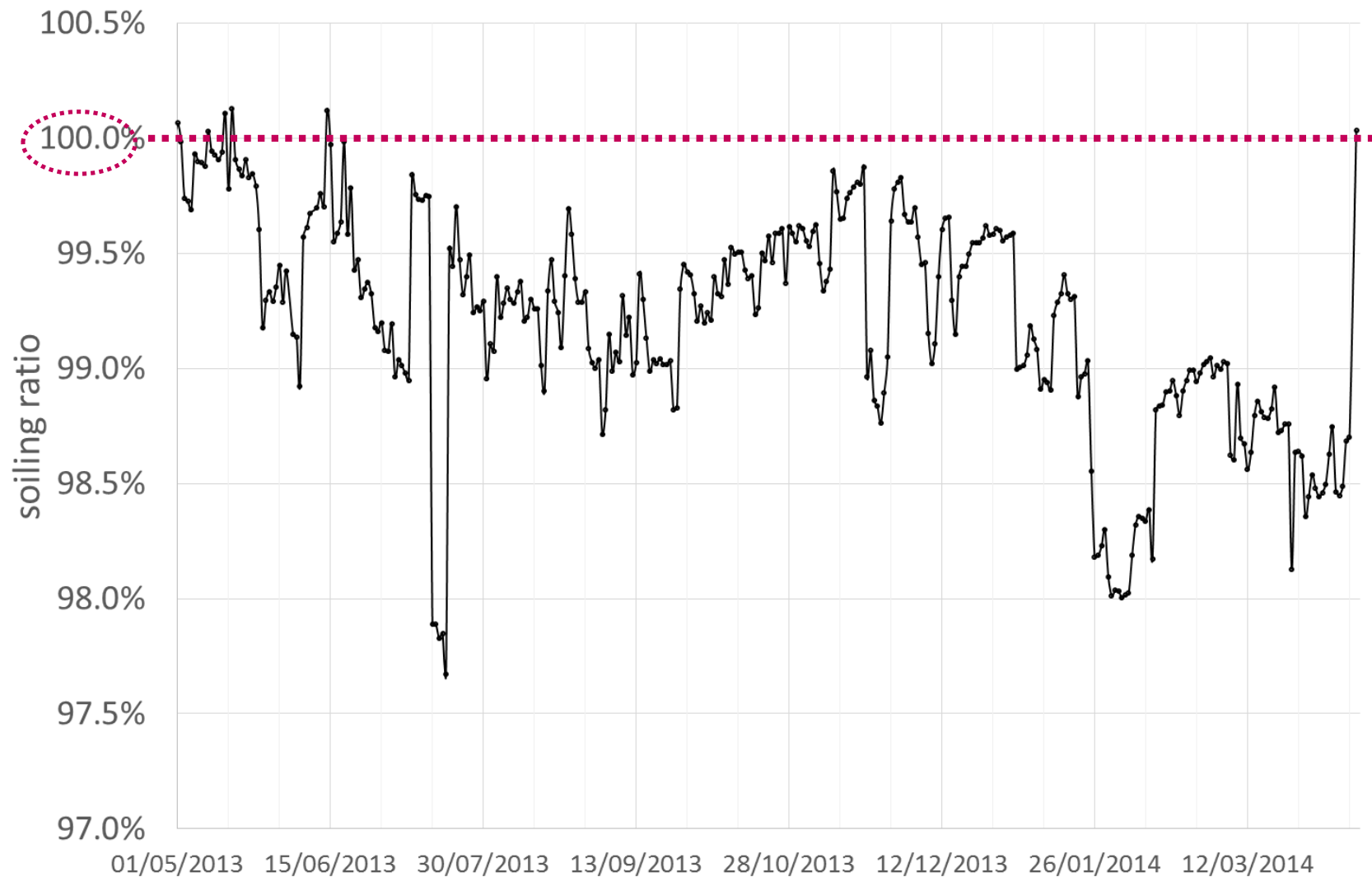
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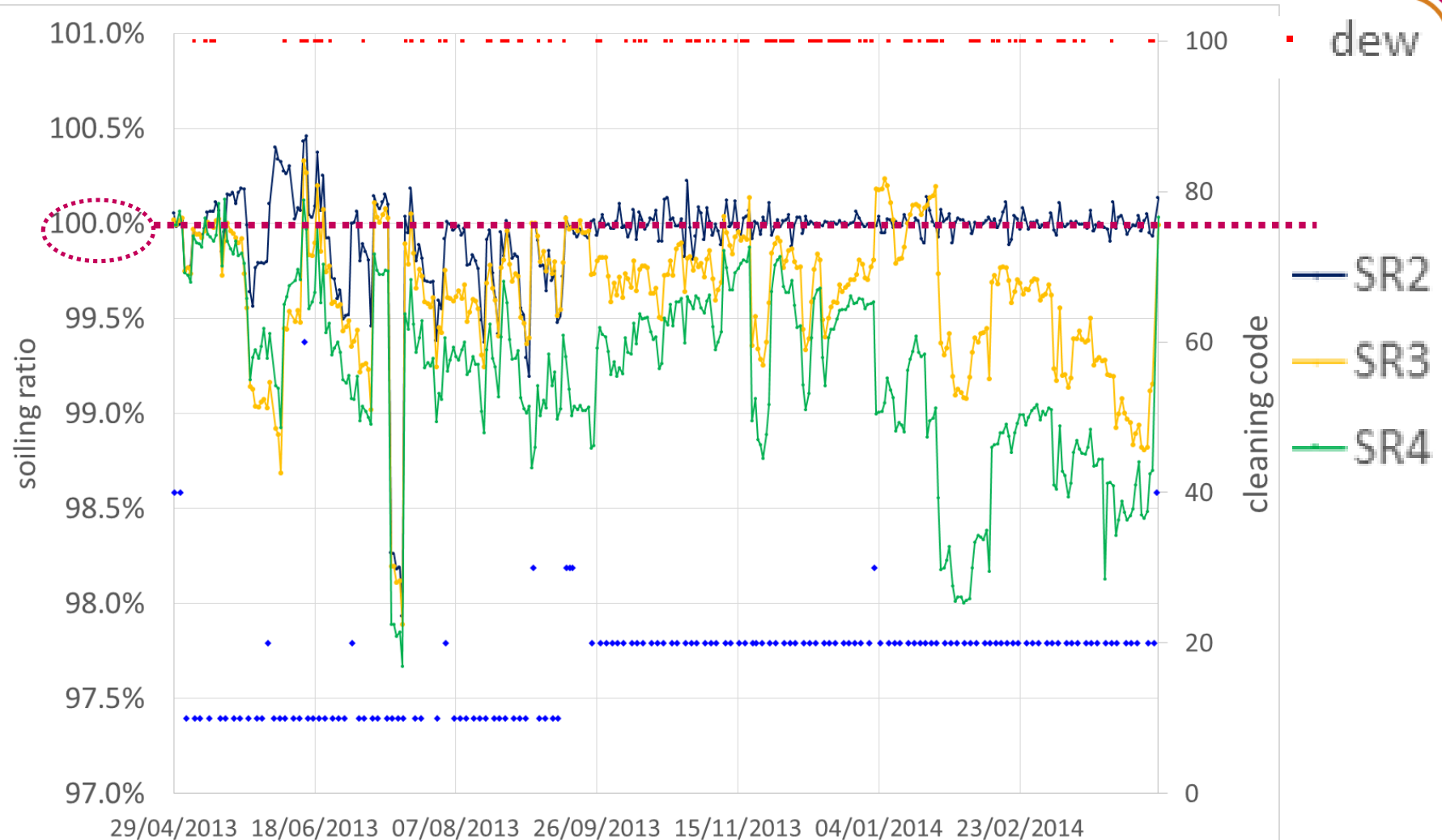
# Data Analysis

- Non-soiling related performance differences had to be adjusted for (electrical characteristics, degradation, inclination angle) - normalisation
- Soiling ratio (SR):
  - The “soiling ratio” is the ratio of the effective irradiance of soiled module over reference module (M2 over M1; M3 over M1; and M4 over M1)
  - A soiling ratio is 1 means no difference in performance due to soiling (M2, 3 or 4 are clean **OR** M1 has soiling)
- Daily averages with filters (3 hours either side of noon, >400W/m<sup>2</sup> incidents)
- Estimate loss based on irradiance weighted average of daily SRs

# Data Analysis – Soiling Ratio Daily Average M4



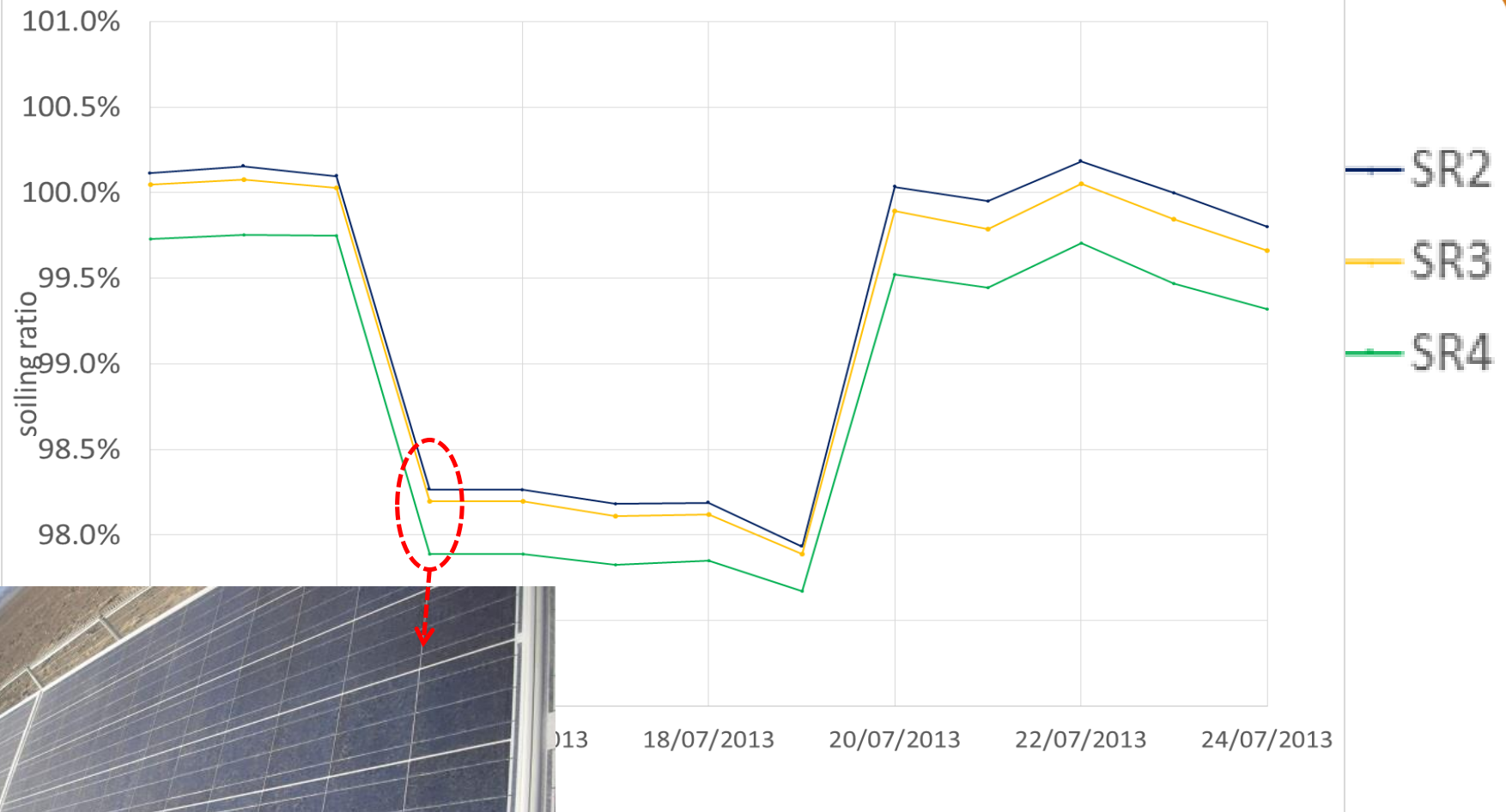
# Data Analysis – Soiling Ratio Daily Average M2, M3 & M4



• cleaning (10 = module 1, 20 = module 1+2, 30 = module 1 to 3, 40 = module 1 to 4, 60 = rain)



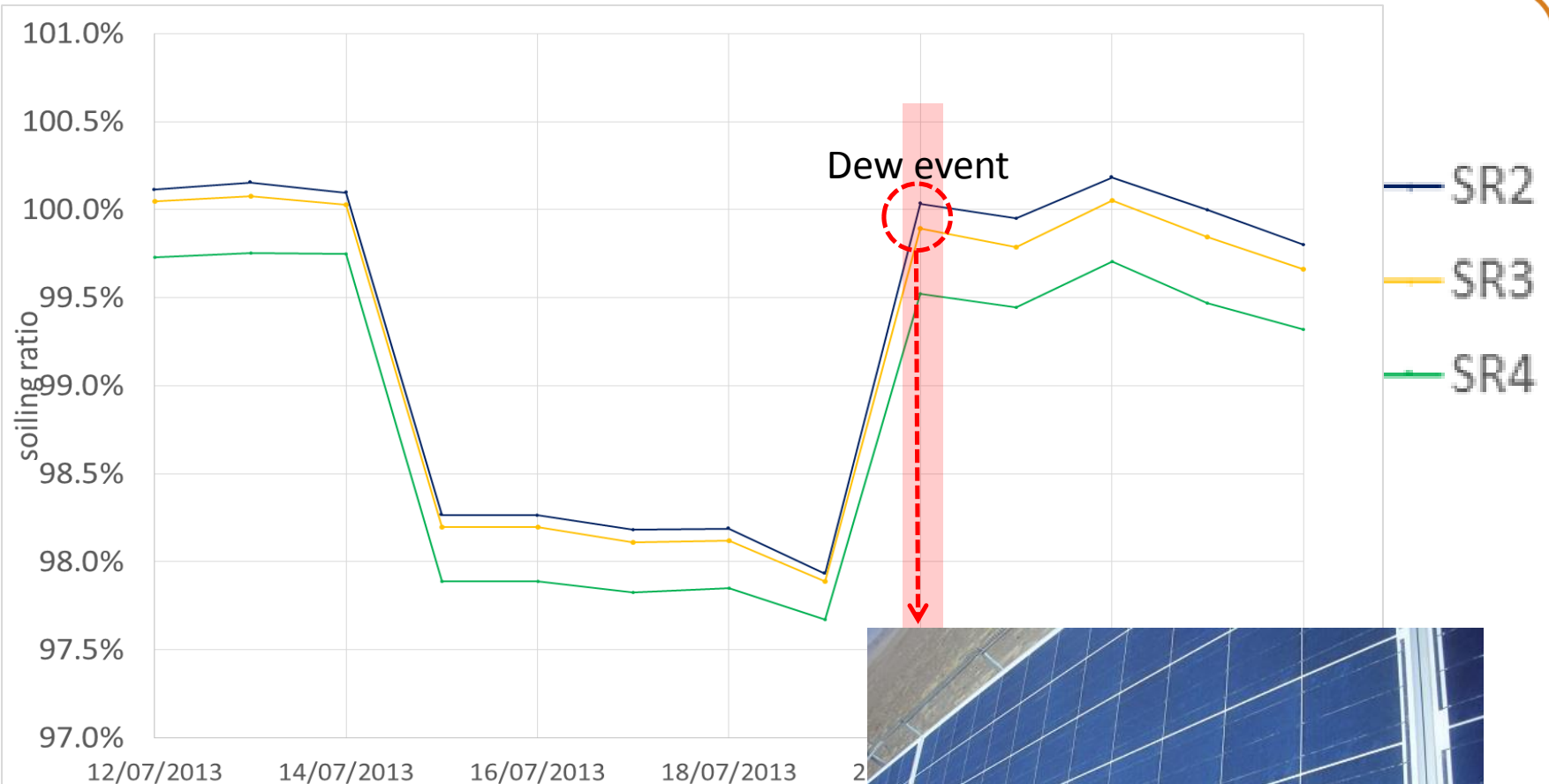
# Sand storm and dew



**15 Jul 2013**

- M1 cleaned, M2, M3 and M4 very dusty → 2% step change

# Sand storm and dew



**20 Jul 2013**

- The dew seemed to remove most of the dust
- Self-cleaning improved performance of M2 – M4 back to 100%



## Sand storm (before and after the dew)





## Dew self-cleaning (Panel 4)



## Dew self-cleaning (Panel 4 – this time less uniform)





# Findings and Limitations

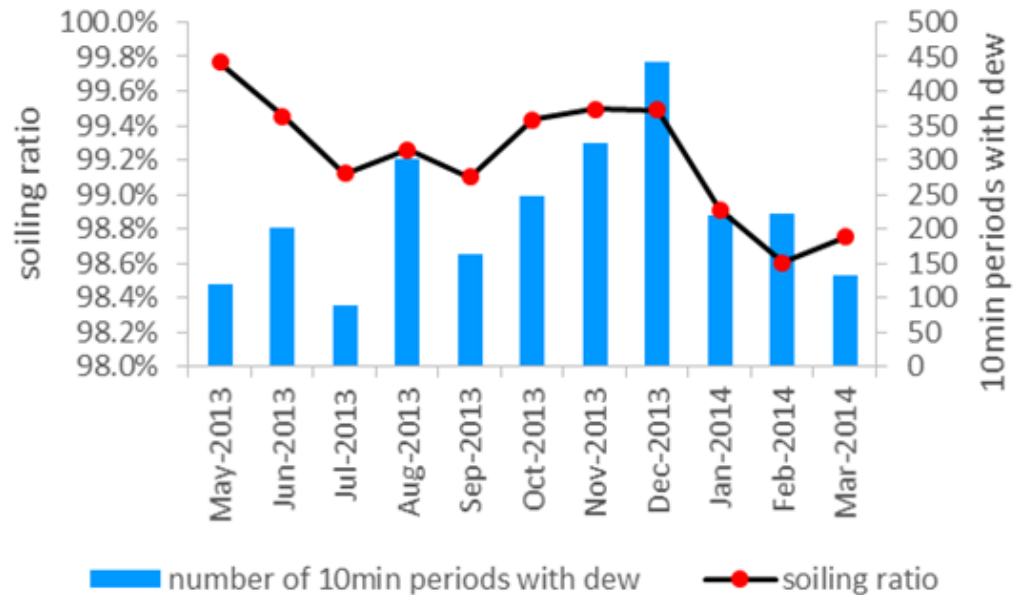


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# Findings for the project

- Unexpected amount of self-cleaning (dew, high wind speed?)
- Dew is the main cleaning driver
- Seasonal dependency on self-cleaning
- Based on the measurements, typical soiling ratios based on  $I_{sc}$ :



	Monthly cleans	3-4 months clean	6-12 months clean
Measured	~0.2%	~0.5%	~1%
Adjusted with safety factor	<0.5%	<1%	<2%

# Limitations

- Set-up:
  - The modules are mounted at height to avoid shading
  - The wind regime will be different in final configuration.
  - The ground is not treated. Vehicle movements (for cleaning) increase dust
  - Our cleaning method (how would this be done in reality?)
  - One point representative for whole site?
- Measurement:
  - “Clean” panel is not always clean - step changes in data
  - Isc with non-uniform soiling; I-V curve and Pmax measurements in future
- Analysis:
  - Scatter in the data
  - Module renormalisations and temp corrections have associated uncertainty
- Future Variability:
  - Does the annual soiling loss change with time of year of starting test?
  - Future variability and changes in conditions

# General Conclusions

- Soiling is VERY location specific in the Atacama
- Measuring at the development stage is important to minimise uncertainties and maximise project value.
- Benefits in defining best practice for measurements.



# What next?



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# What next?

- The renewable energy technical group (RETG or GTER) is working in Chile alongside ACERA (the Chilean renewable energy association).
- As part of their tasks there is a soiling work stream. Several companies are working together to:
  - agree on best practice for soiling measurements;
  - try to characterise the different areas in the desert (according to soil and environmental conditions);
  - study the effect of soiling per region on Opex and Capex.
  - Anyone interested in participating, can email [patricia.darez@mainstreamrp.com](mailto:patricia.darez@mainstreamrp.com)

# Questions

Thank you.



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Extra slides...



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# Dew analysis

