Intrinsic performance loss rate: decoupling shading losses from photovoltaic system data for reliable degradation estimations

13th SOPHIA PV-Module Reliability Workshop | JRC (Ispra)

SOPHIA European Research Infrastructure

3S Swiss Solar Solutions | EPFL | PV-lab IEM NEUCHATEL

Hugo Quest, PhD student

Co-authors: Alessandro Virtuani, Pascal Müller, Alejandro Pena Bello, Nicolas Wyrsch, Christophe Ballif

20 April 2023

Outline

1 Current status of PLR

2 New methodology

3 Results

4 Conclusion

1 | General steps & pressure points

1

Data treatment

- Data availability & quality
- Data filtering

- Use most commonly available sources
- Physics-based filtering
- Implement a fault detection algorithm

- Multiple data sources w/ varying quality levels
- No standardised filtering methods
- How to deal with reversible faults and failures?

2

Performance metric

- Metric computation
- Aggregation strategy

- Performance Ratio (PR)
- Compare different aggregation strategies

- No standard metric
- No standard aggregation strategy

3

PLR calculation

- Model application
- Uncertainty determination

- Year-on-year method
- Minimise statistical uncertainty

- Multiple choices of PLR models
- Combination of analytical & statistical uncertainties

Lindig et al. (2022), doi: 10.1088/2516-1083/ac655f

1 | Research gaps

Research on PV fault detection is separated from reliability assessments in literature, but they should be dealt with **in parallel**.

Reversible faults such as partial shading can significantly bias a PV system’s performance loss rate (PLR).

This work aims to decouple reversible losses from PV output data, leading to the definition of the **intrinsic PLR**.

Fairbrother et al. (2021), doi: 10.1002/solr.202100583

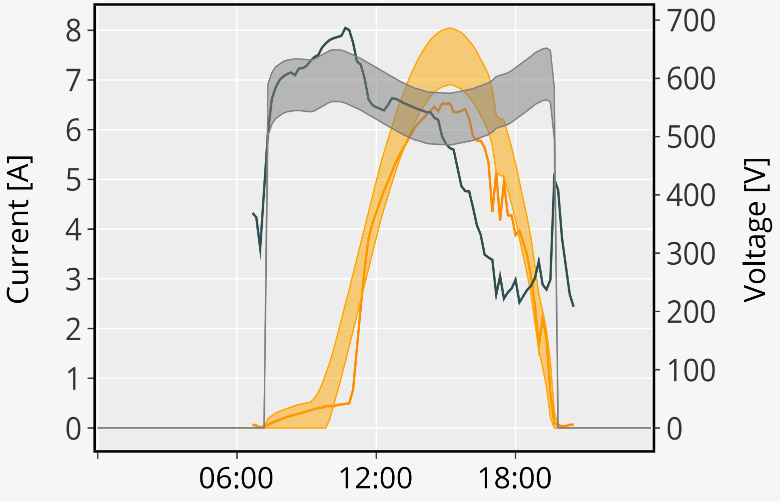
Outline

1. Current status of PLR
2. **New methodology**
3. Results
4. Conclusion

2 | Main analysis steps

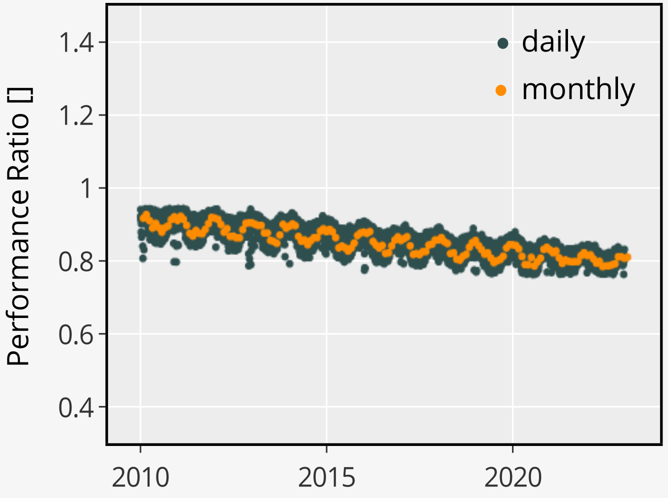
Step 1

Fault detection and diagnosis algorithm (FDDA) to identify reversible losses such as shading patterns.



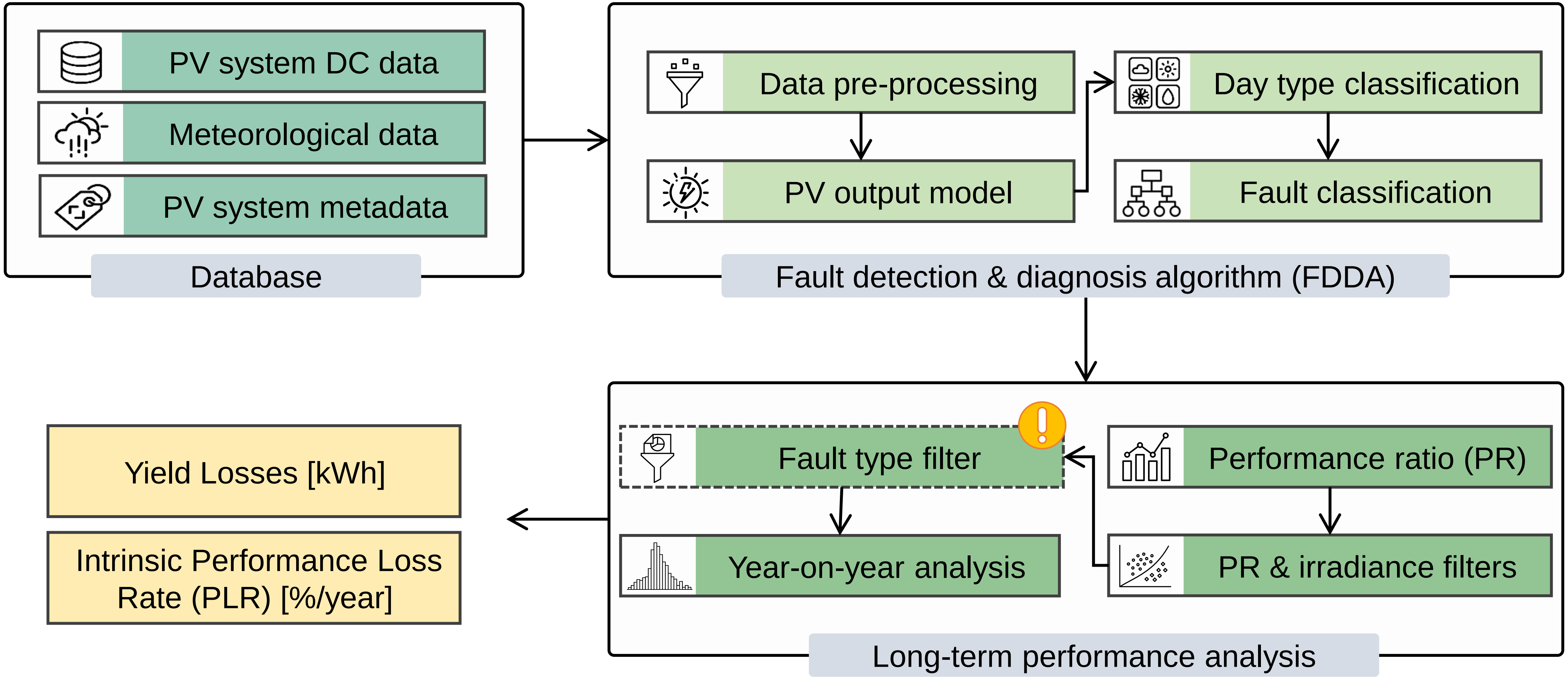
Step 2

Compute intrinsic PLR with fault type filtering, eliminating the effect of reversible faults.



Quest et al. (2022), doi: 10.13140/RG.2.2.16943.82085
Özkalay et al. (2021), doi: 10.4229/EUPVSEC20212021-5DO.2.1

2 | Methodology flowchart



Quest et al. (2022), doi: 10.13140/RG.2.2.16943.82085
Özkalay et al. (2021), doi: 10.4229/EUPVSEC20212021-5DO.2.1

Outline

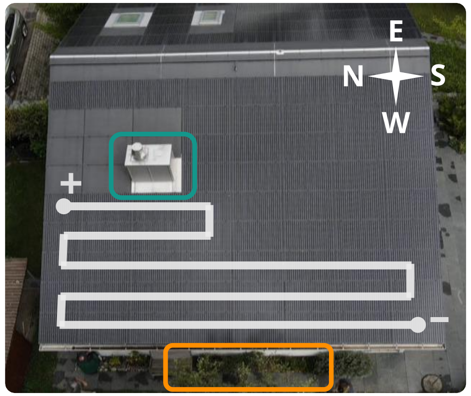
1 Current status of PLR

2 New methodology

3 **Results**

4 Conclusion

3 | Case study – step 1: FDDA



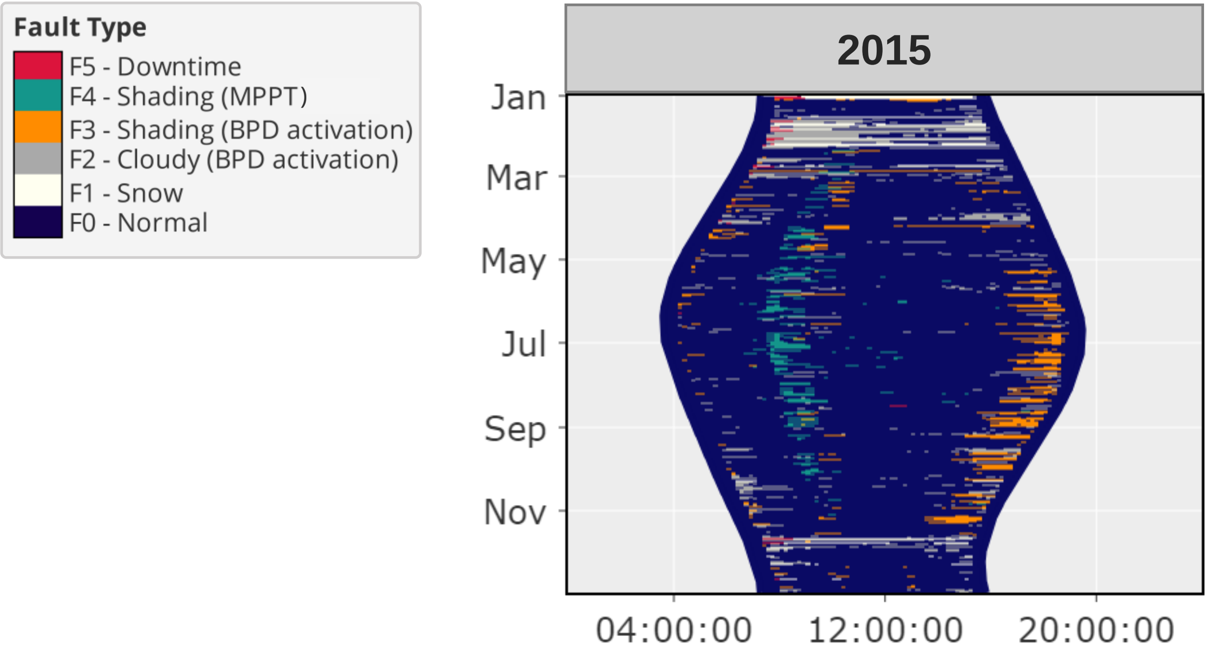
System size: 21.3 kWp

String size: 5.22 kWp

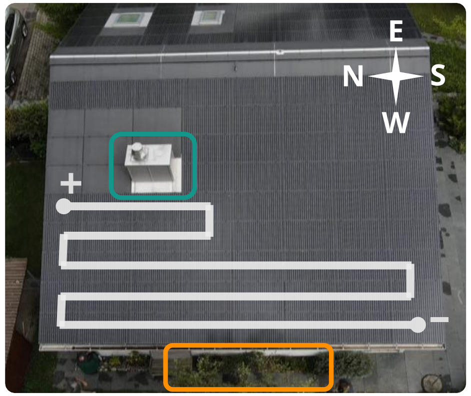
Orientation: 264°

Tilt: 24°

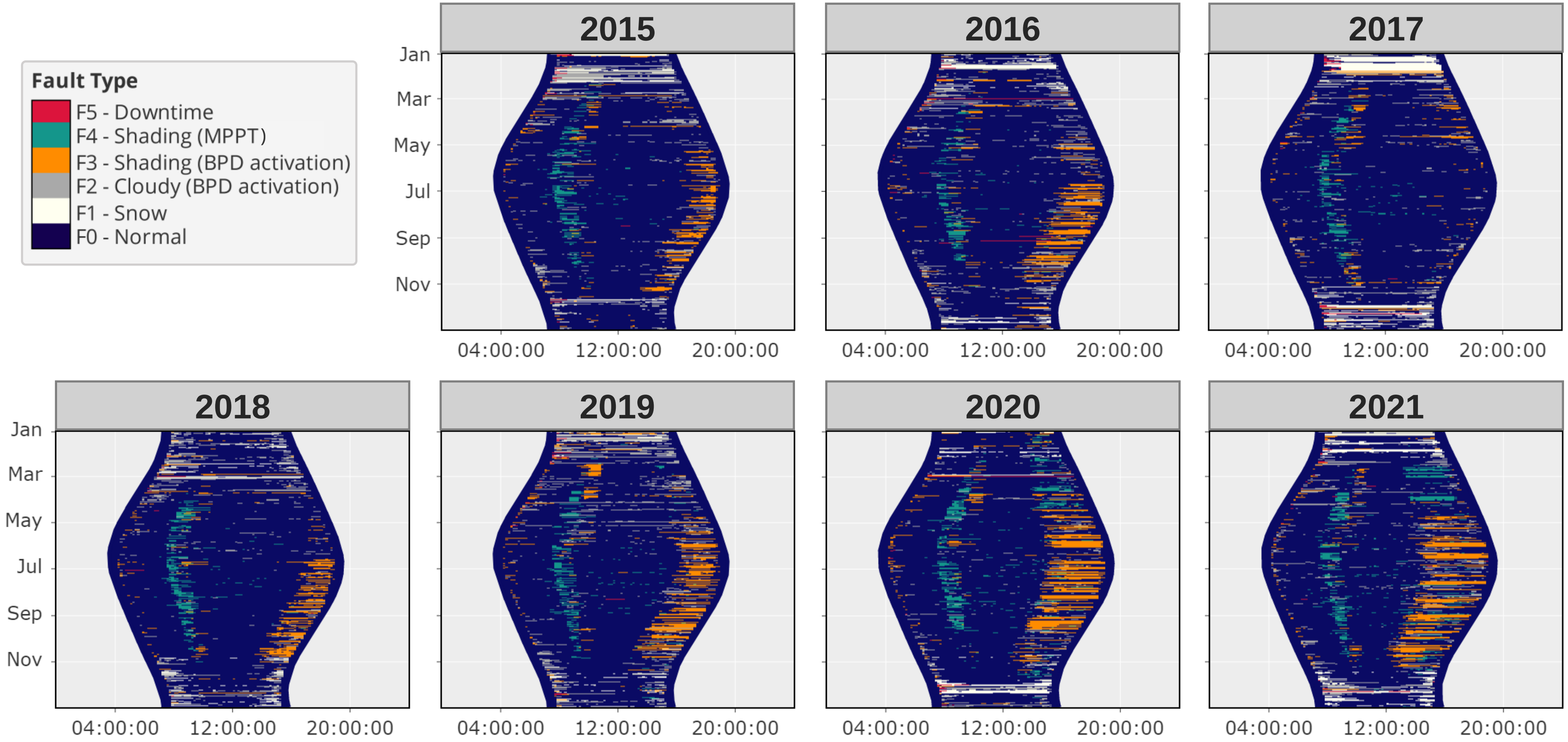
Location: CH-3033



3 | Case study – step 1: FDDA



System size:	21.3 kWp
String size:	5.22 kWp
Orientation:	264°
Tilt:	24°
Location:	CH-3033

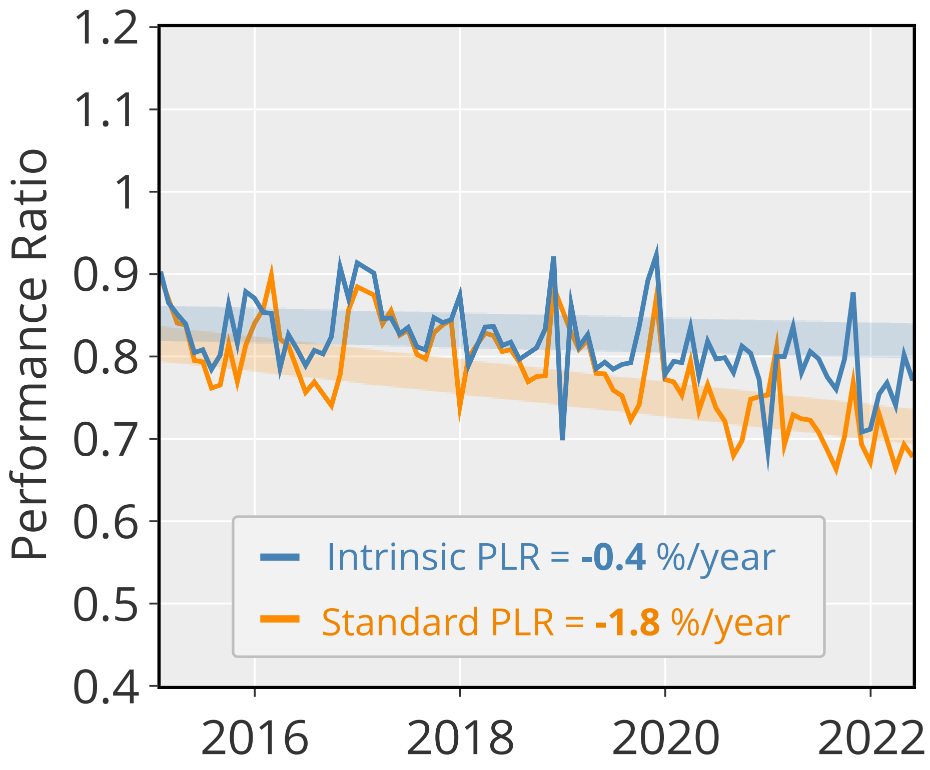


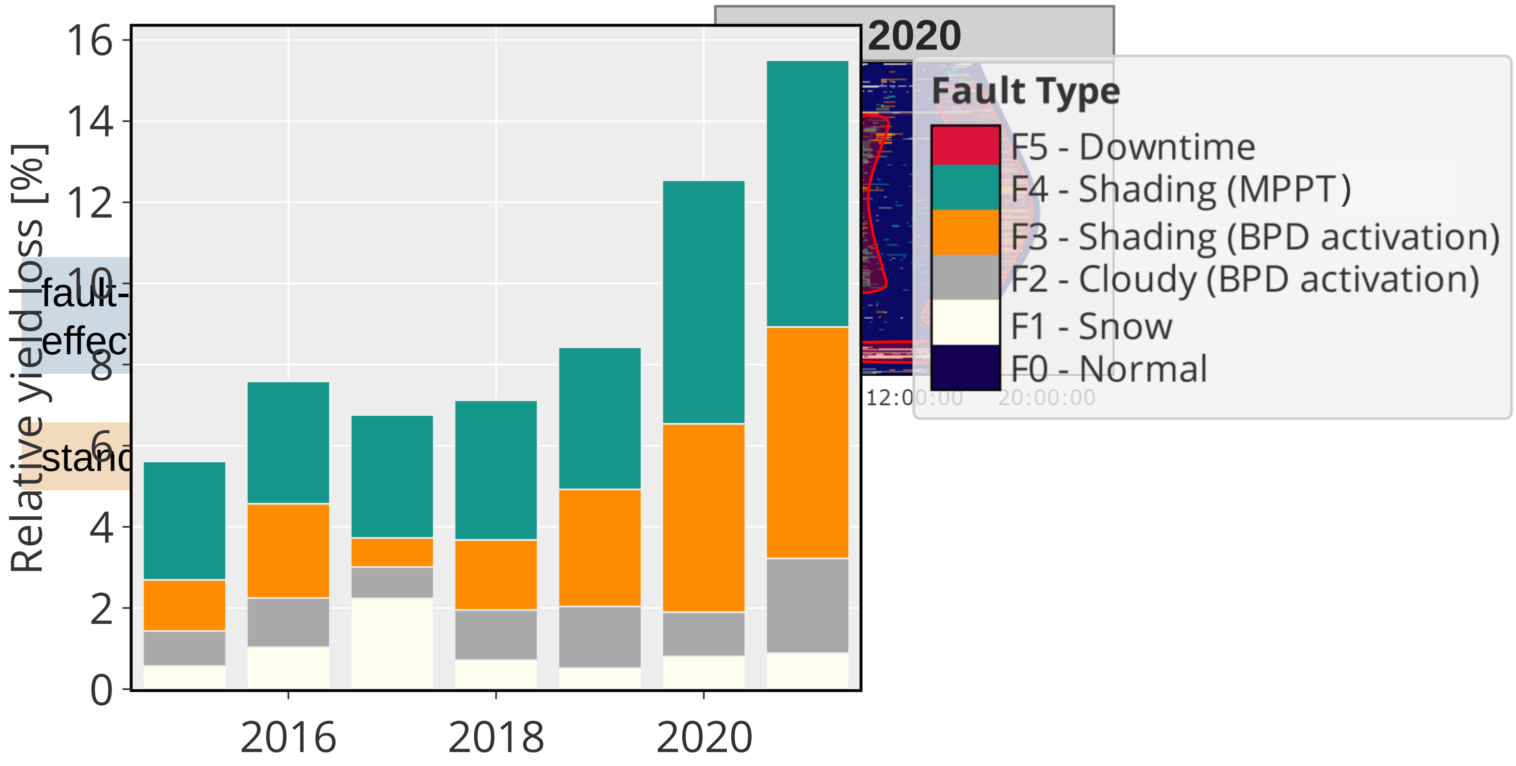
Recurring **shading losses** due to rooftop chimney and nearby tree.

Increase of tree shading over time, causing increased **bypass diode activation**.

Anomaly in 2017 – decreased shading, indicating the tree was trimmed.

3 | Case study – step 2: intrinsic PLR



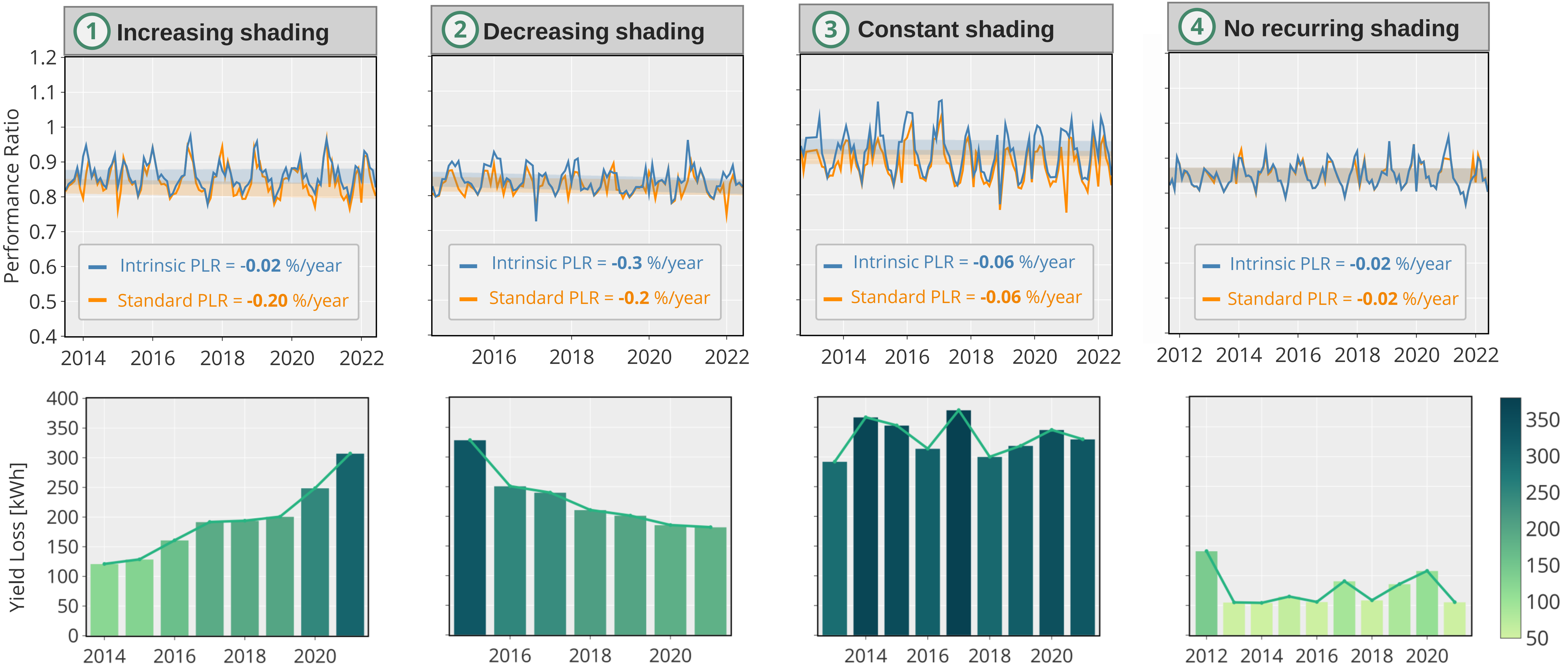


The **intrinsic PLR** is 80% higher compared to the standard method.

3× Shading losses increase by a factor 3 between 2017 and 2021, leading to a **drift in PR**.

One **broken bypass diode**: recurring shading can cause permanent, irreversible faults.

3 | BIPV fleet analysis – 4 patterns of PLR bias



Outline

1 Current status of PLR

2 New methodology

3 Results

4 **Conclusion**

4 | Conclusion

The addition of FDD analysis within PLR pipelines offers a solution to avoid the influence of reversible effects, enabling the determination of what we call the **intrinsic PLR**.

A BIPV fleet analysis revealed **four typical patterns of PLR bias** due to reversible loss effects: overestimation of PLR, underestimation of PLR, shift in PR or stable PLR.

Next steps should include on-site analysis of systems affected by recurring losses in order to **correlate them to permanent, irreversible faults**.

Thank you for your attention

Questions ?

Q A

3S

Acknowledgements

3S Swiss Solar Solutions

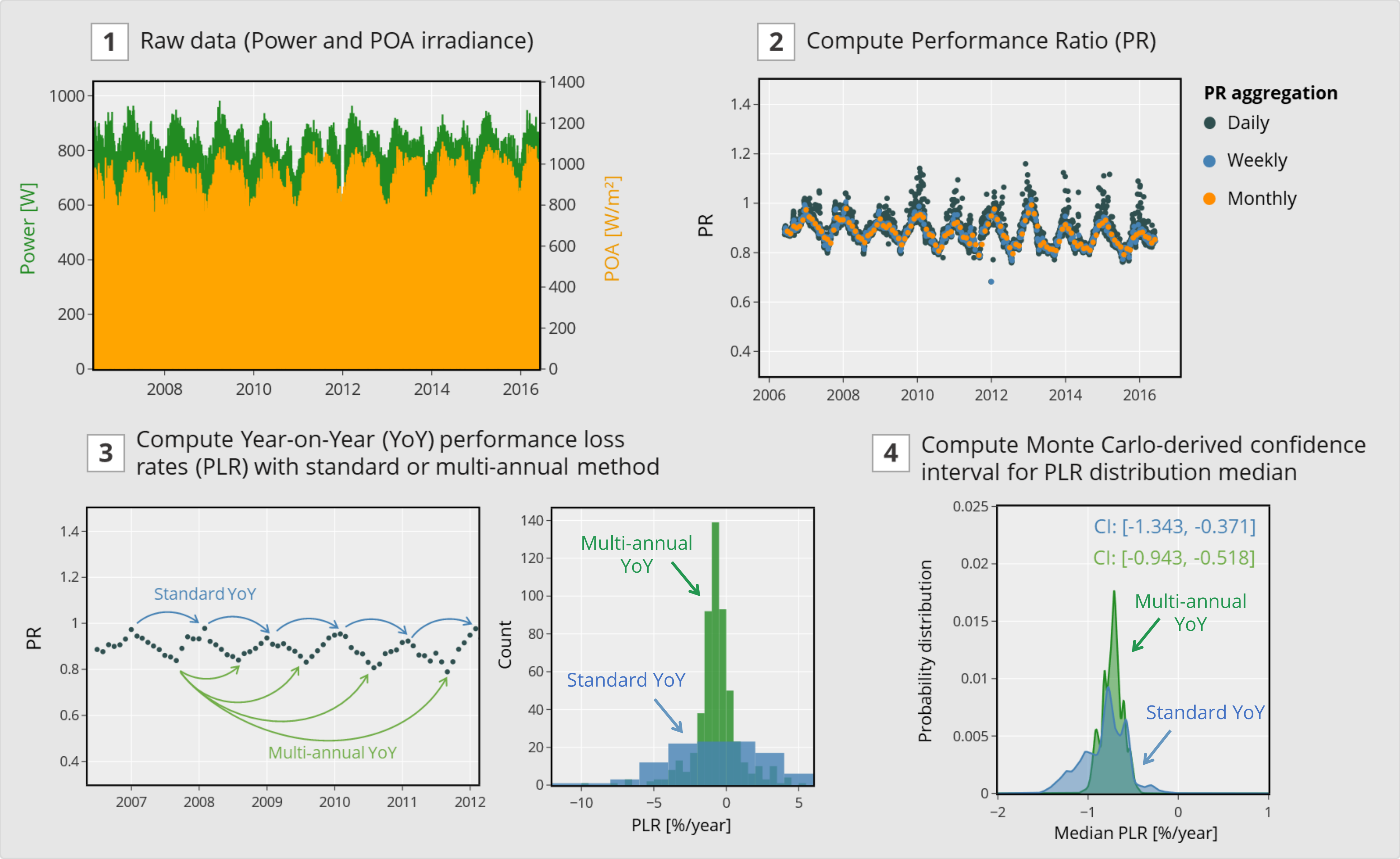
EPFL

PV-lab IEM NEUCHATEL

SOLCAST

Baur AG BAUR Bedachungen / Spenglerei / Solarstrom

Appendix | PLR uncertainty: multi-annual YoY



Appendix | PLR uncertainty: multi-annual YoY