AuSeSol-AI
AI methods for autonomous and self-optimizing solar energy generation

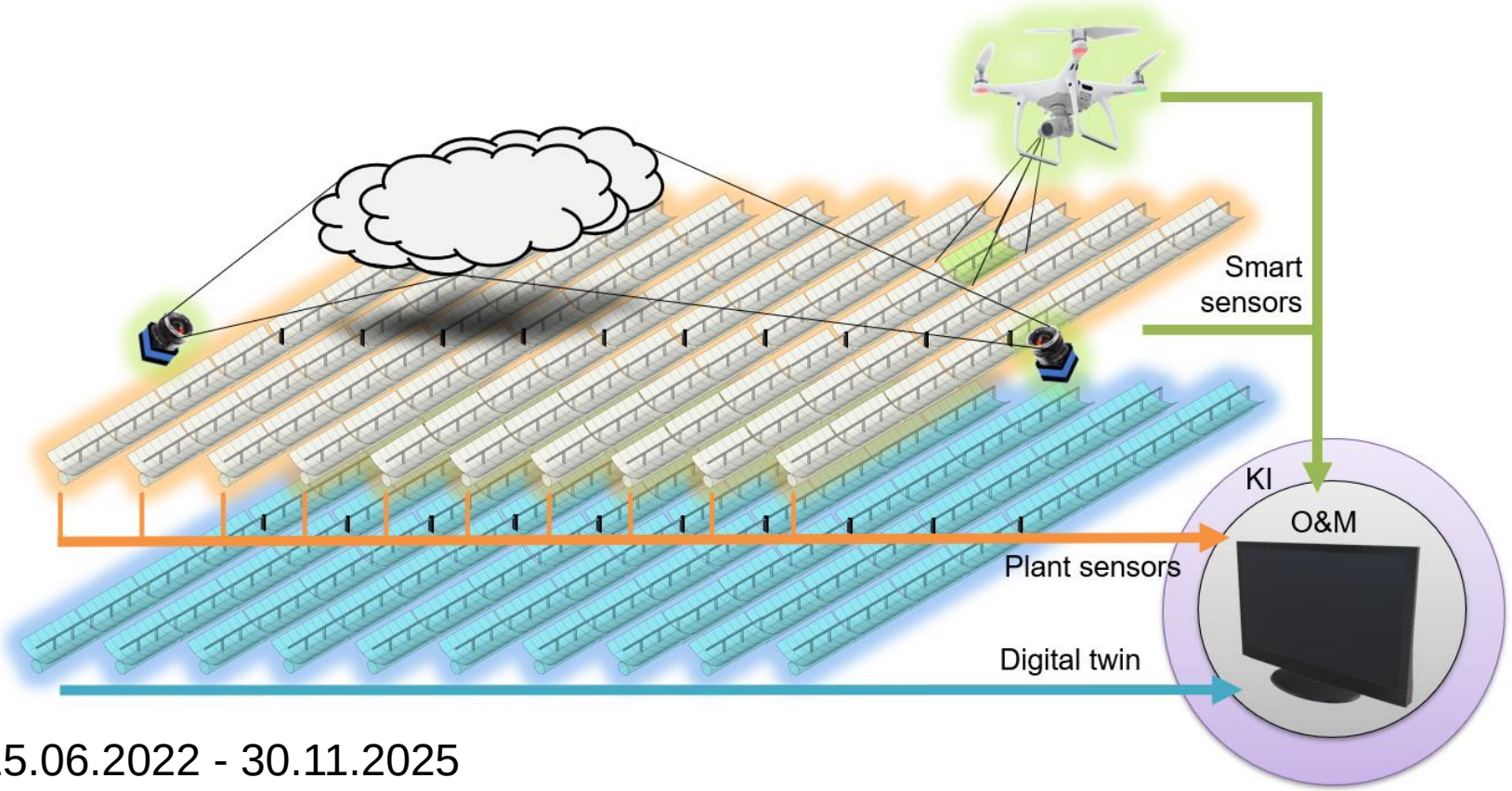


Image from DLR

Project runtime: 15.06.2022 - 30.11.2025

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Technische Universität München

fortiss

JTI

cspservices
concentrating solar power services

JÜLICH
Forschungszentrum

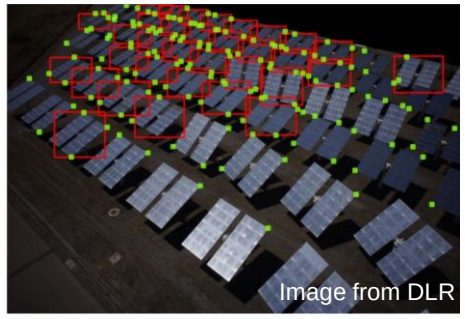
Marquesado Solar

Federal Ministry
for the Environment, Climate Action,
Nature Conservation and Nuclear Safety

AuSeSol-AI
Selected results for today's webinar

Loop-wise mass flow monitoring in parabolic trough fields

Dr. –Ing. Alex Brenner

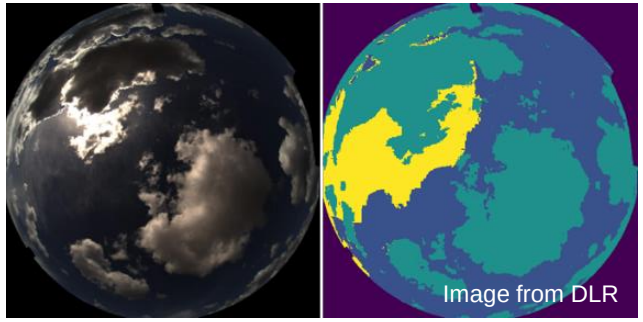


Training of a machine learning model for processing airborne solar field images without labeled data

Rafal Broda

Towards Intelligent Operation of CSP Towers

Mathias Kuhl



Generative AI for All-Sky Imager-Based Solar Nowcasting

Dr. –Ing. Bijan Nouri

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Technische Universität München

fortiss

JTI

cspservices
concentrating solar power services

JÜLICH
Forschungszentrum

Marquesado Solar

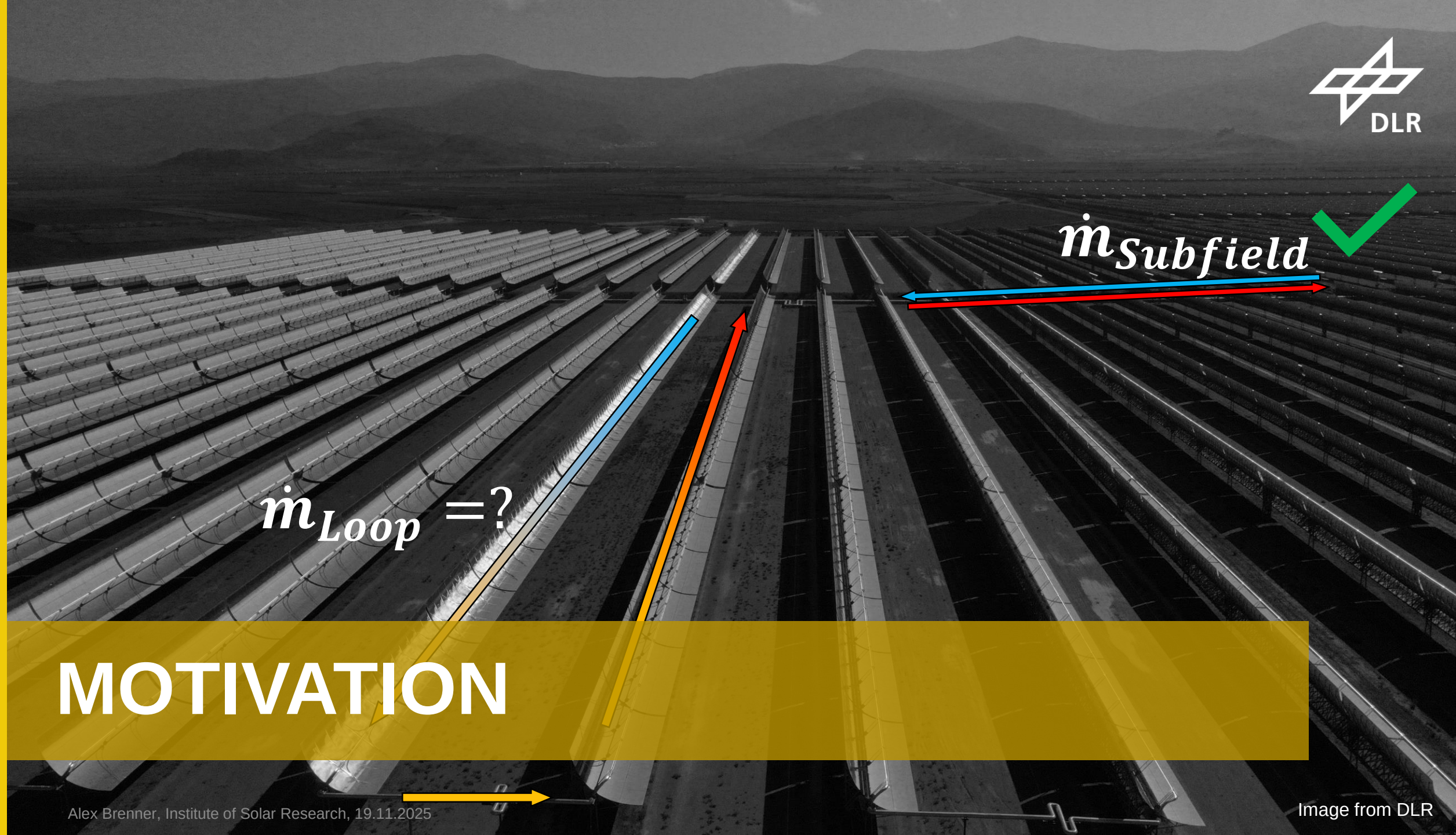
Federal Ministry
for the Environment, Climate Action,
Nature Conservation and Nuclear Safety

LOOP-WISE MASS FLOW MONITORING IN PARABOLIC TROUGH FIELDS

Webinar – Digital solutions for monitoring and optimizing CSP and PV plants

Alex Brenner

19.11.2025



MOTIVATION

Image from DLR

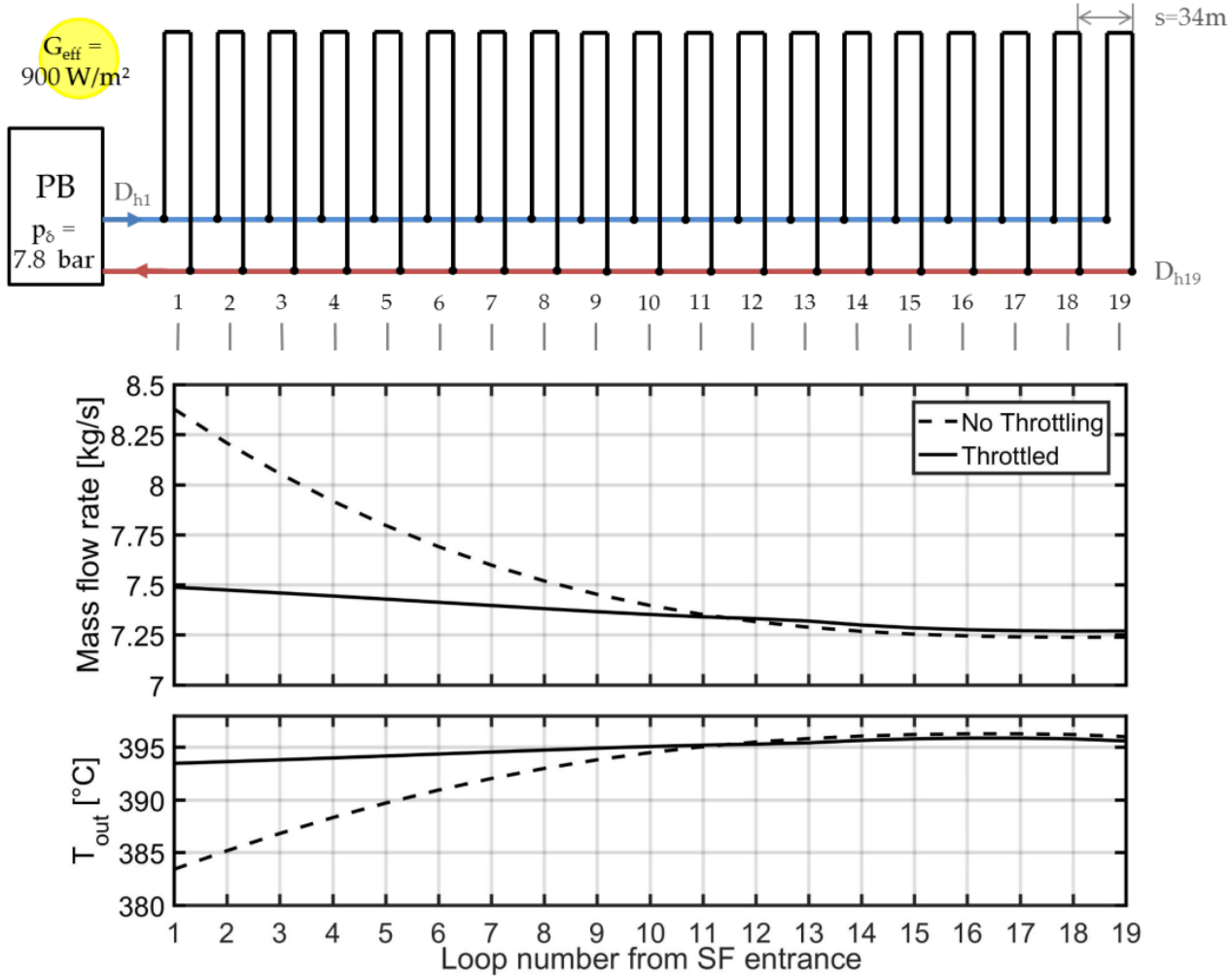
Motivation
Hydraulic balancing and performance monitoring

Application 1: Hydraulic balancing

- Relative flow distribution necessary
- Initial hydraulic balancing during commissioning
  - Aim: Equal loop outlet temperatures under nominal conditions
- Throttle valves available for each loop
- Adjustments during operation also possible

Application 2: Performance monitoring

- Absolute values of loop mass flow is necessary
- So far, evaluation of loop performance not possible without additional measurement equipment



From: Noureldin, Kareem (2019): Modelling and Control of Transients in Parabolic Trough Power Plants with Single-Phase Heat Transfer Fluids. Dissertation. University, RWTH Aachen. Faculty of Mechanical Engineering. Available online at https://publications.rwth-aachen.de/record/771557/files/771557.pdf

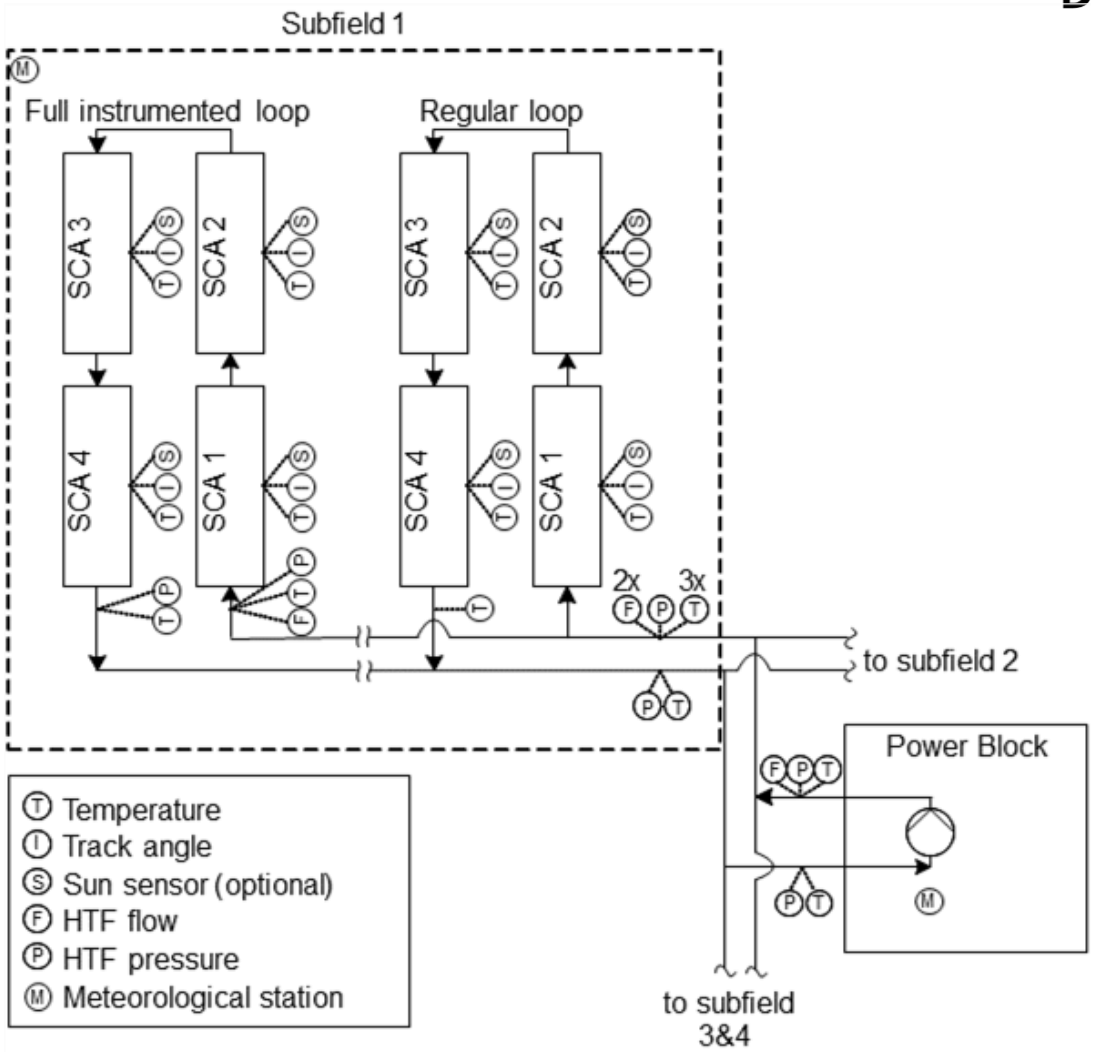
Motivation
Available measuring equipment

What we do not have

- Loop (mass)flow is usually not determined
- Measurements only available at certain positions in the field
- Retrofitting is often expensive, or not possible
  - Numerous measuring instruments would be required

What we have

- Temperature sensors are often already installed at collectors
- Collector can change heat input to HTF by adjusting focus, thus temperature can also be changed



From: Brenner, Alex; Hirsch, Tobias; Röger, Marc; Pitz-Paal, Robert (2021): State-of-the-Art Measurement Instrumentation and Most Recent Measurement Techniques for Parabolic Trough Collector Fields. In *Energies* 14 (21), p. 7166. DOI: 10.3390/en14217166.

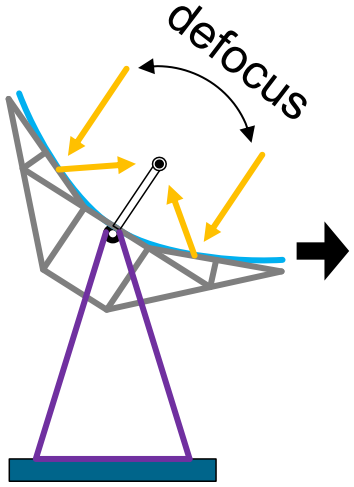
APPROACH

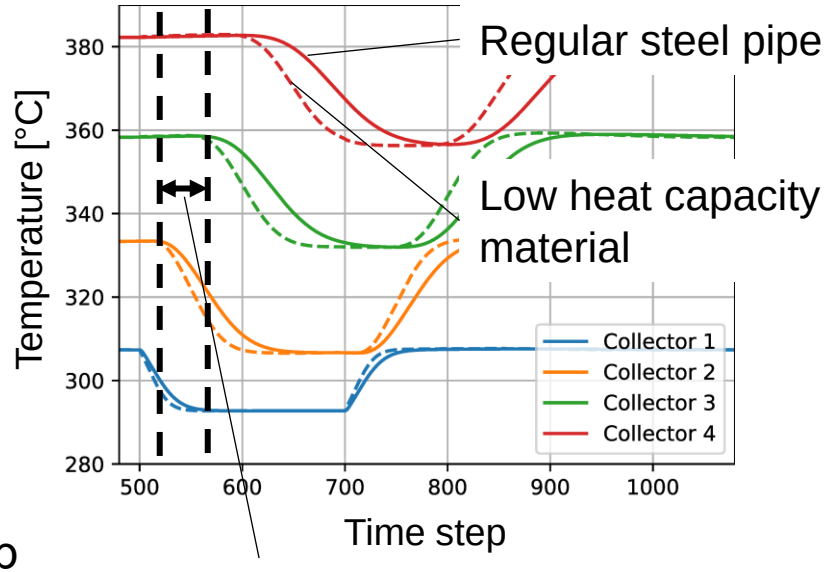
Image from DLR

Approach
Using temperature gradients as tracer to determine fluid flow

Challenge

- Thermal interaction with pipe shifts fluid runtime and runtime of temperature signal
  - Correction is required





Temperature "runtime" t_{Temp}

Image from DLR

Generated temperature gradients

- First collector is defocused: Temperature gradient "flows" through loop
- Gradient measurable at following sensors
- Repeating signal is also possible
- Goal of this procedure: Generation of clearly recognizable temperature gradients with a small disturbance to plant operation

- **Proof-of-concept study validated with test data from Andasol 3**

Approach
Transient simulation as basis for the correction function

- Correction function should fit for various pipe material, process and geometric properties
- Transient simulations with Virtual Solar Field for thermal oil and solar salt with differing setups
- The correction function summarizes the simulation results and solves the inverse problem

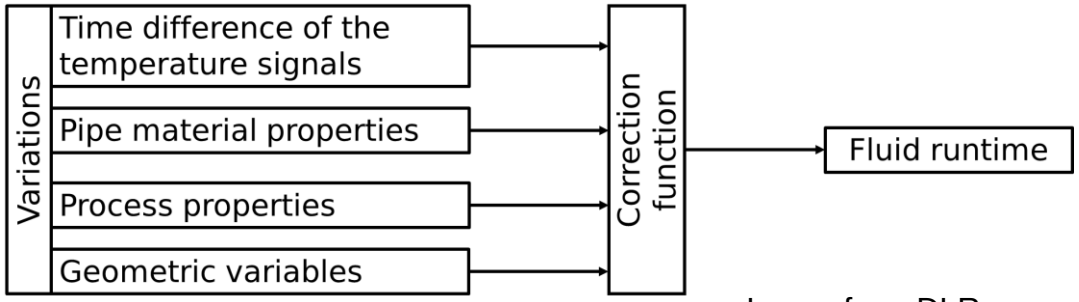


Image from DLR

- Runtime of temperature signal is the measured input for the correction function.
- Compared to other approaches: We can calculate absolute values!

RESULTS

Image from DLR

Results
Validation with temperature signals from Andasol-3

- Multiple defocusing tests in Andasol-3 on January 23, 2023
- 12 experiments with 38 collectors: 456 defocusing procedures
  - 26 excluded due to faulty signals
- Runtime between collector 3-4 is used
- Mass flow used as comparison with subfield flow (compensation of HTF density influences)

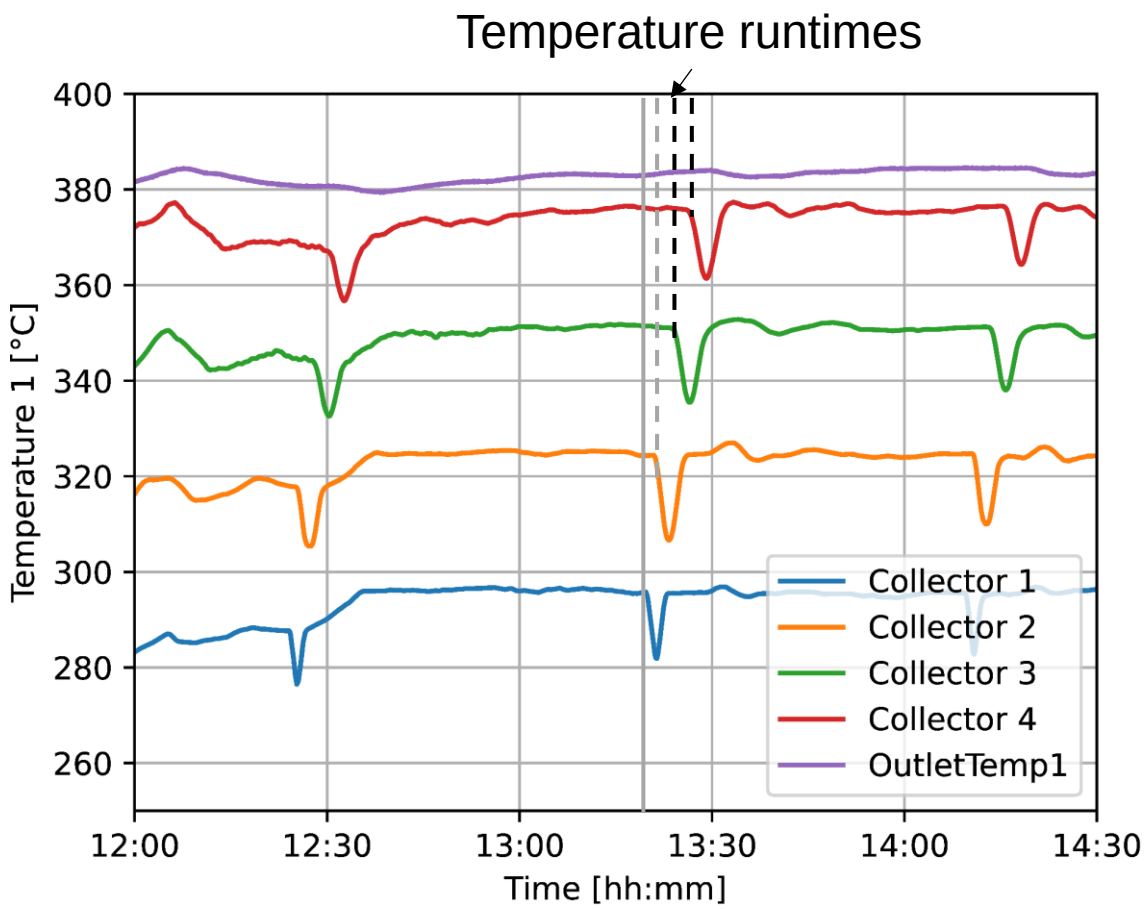


Image from DLR

Results
Validation with temperature signals from Andasol-3

- Mass flow is compared between subfield flow meter and defocus procedure
- Defocus procedure systematically underestimates mass flow by approx. 6 %
  - Applying a linear correction reduces error to MAPE=1.74%
- Subfield flow meters have uncertainty as well

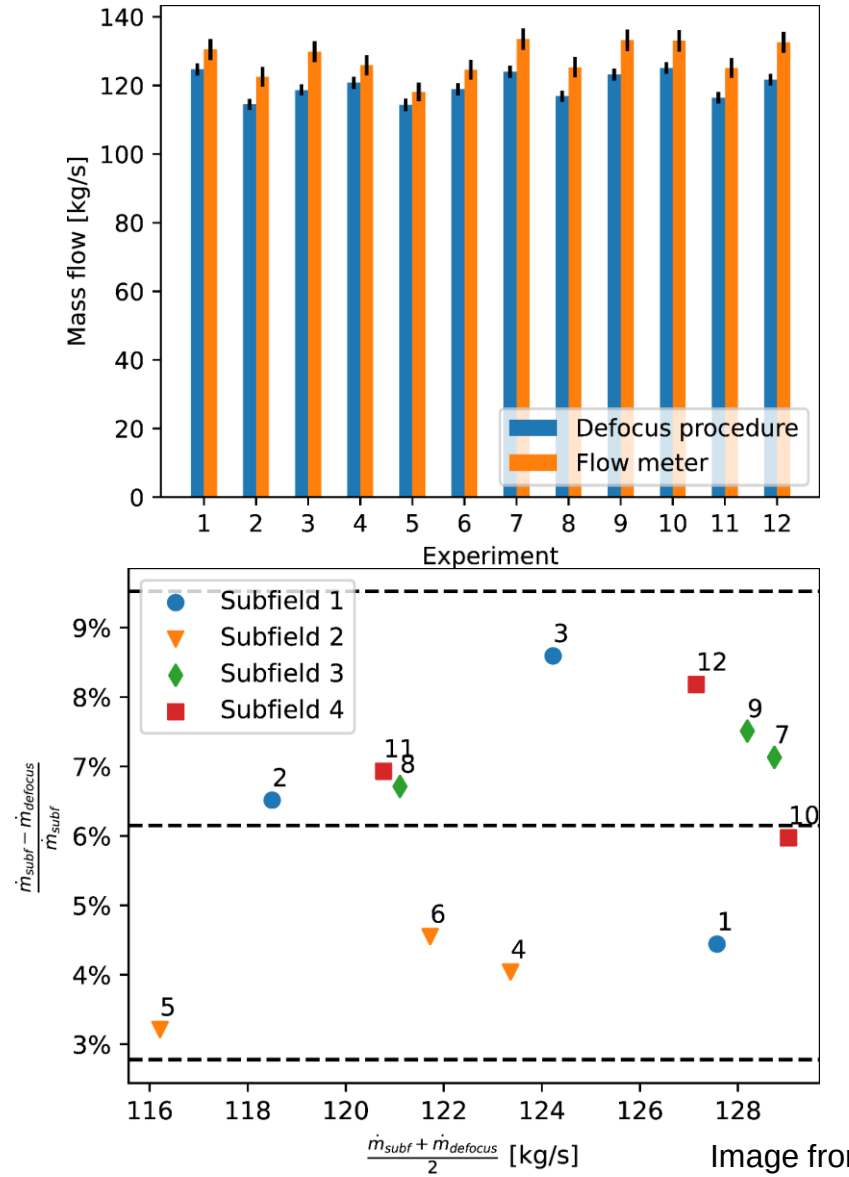


Image from DLR

Results
Impact on plant operation

- Defocusing procedure for every loop every 30 minutes decreases solar yield slightly < 1.25%
- Influence on outlet temperature due to collector defocusing is small approx. 2 K within 5 minutes
- The temperature change due to **simultaneous** defocusing leads to a change of fluid velocity, and a temperature increase (~ 9 K)
  - Can be prevented by a short time delay between defocus procedures

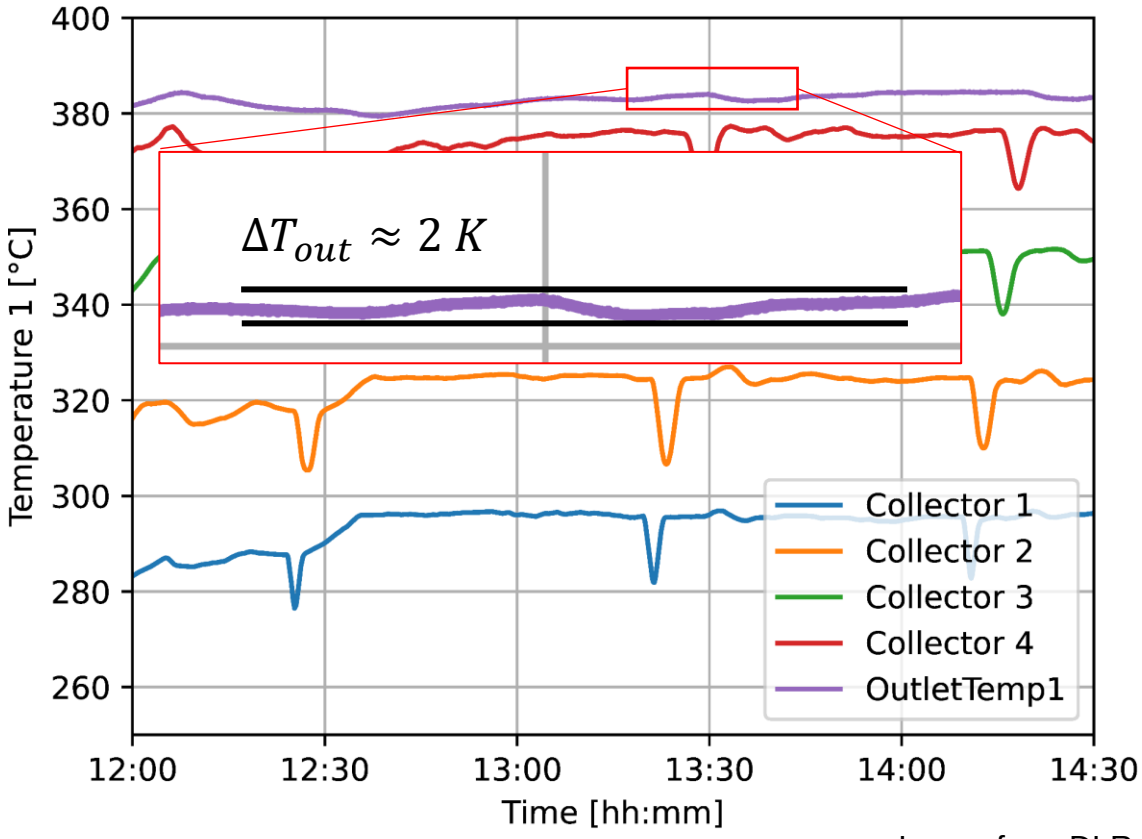


Image from DLR

Summary and Outlook

- No additional hardware required, low cost flow measurement
- Error compared to flow meter MAPE = 6.15%
- Paper "*Brenner et al., Volumetric flow determination in parabolic trough plants using the time offset of temperature gradients*" currently under review
- Calibrated instrumentation needed for further investigations
- Next Steps: Develop methods for asymmetric solar field layouts, e.g. process heat plants

Solar process heat plant, Turnhout, Belgium. Photo from Avery Dennison

THANK YOU FOR YOUR ATTENTION

Alex Brenner | alex.brenner@dlr.de

The authors would like to thank Marquesado Solar for providing the data as part of the AuSeSol-AI project.

Federal Ministry
for the Environment, Climate Action,
Nature Conservation and Nuclear Safety

DLR