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Automated Mass Flow Distribution Measurement in linear Concentrating Solar Systems

Thomas Kraft
SolarPACES Conference
Almería, 24th of September 2025
www.ise.fraunhofer.de

Why is mass flow measurement in concentrating solar systems important?

Background

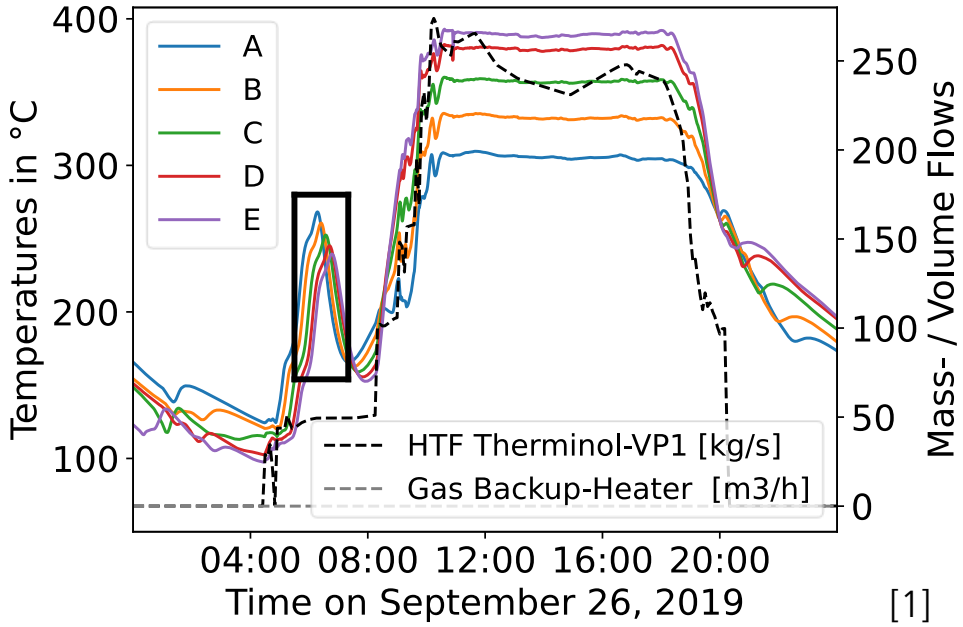
Importance of mass flow for plant efficiency

- High, constant outlet temperature at high mass flow essential for efficient solar field operation
- Solar field outlet temperature of CST systems typically controlled by mass flow
- Knowledge of mass flow gives relevant information about local efficiencies

Is there an **automated**, **simple, secure** and **cost-effective method** for **mass flow distribution measurement**?

How does measurement of mass flow distribution work?

Time-of-flight method



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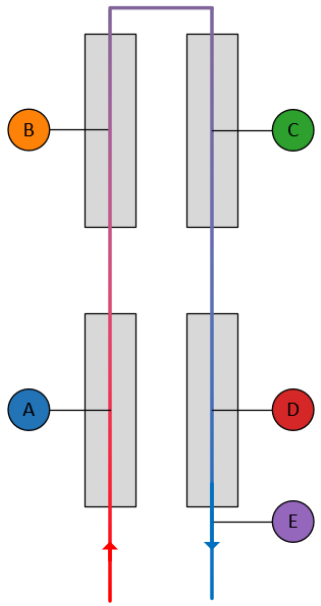

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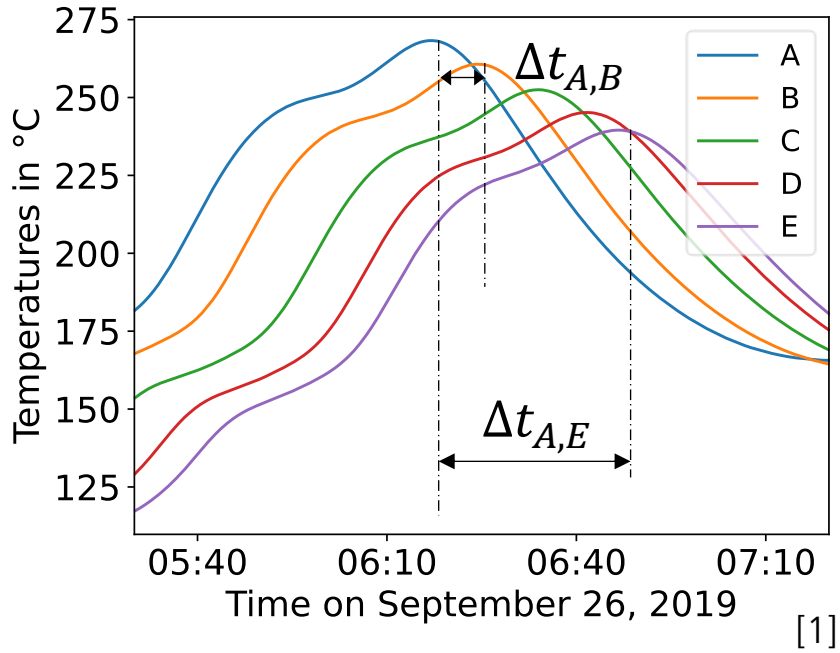

[1]

$$\dot{m} = \dot{V} \cdot \rho = v \cdot A \cdot \rho = \frac{\Delta l}{\Delta t} \cdot \frac{\pi}{4} d^2 \cdot \rho(\vartheta) \cdot f_{corr}$$

→„Thermal time-of-flight method“

→ Here: Venting at reduced mass flow

Defined general conditions for this investigation:

- Constant mass flow between measurements
- Uniform thermal step response without superimposing

[1] Kraft et al. (2024): Mass Flow Distribution Measurement in Concentrated Solar Power Plants via Thermal Time-of-Flight Method. In Solar Energy.

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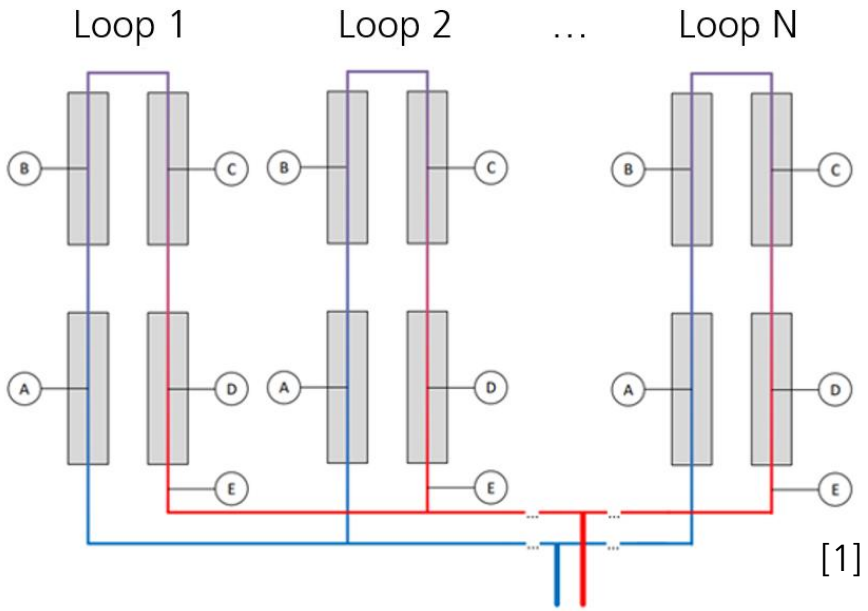
How does measurement of mass flow distribution work?

Time-of-flight method



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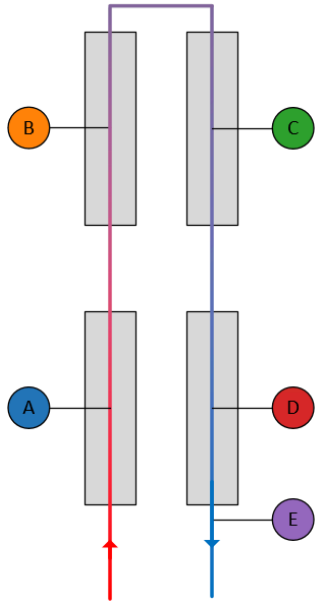

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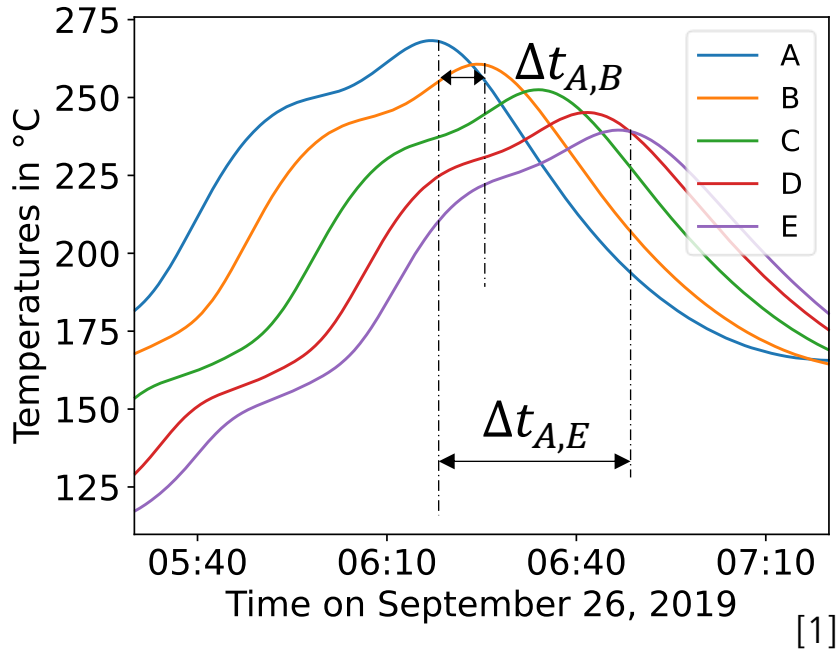

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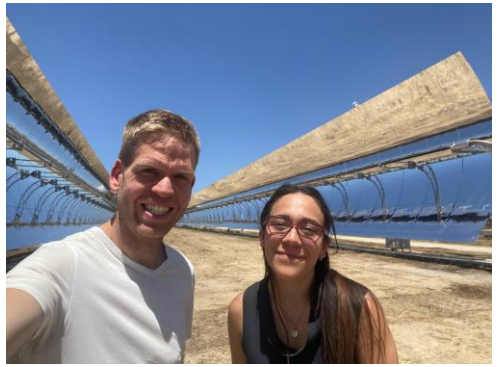
Where is mass flow distribution measurement applicable?

Time-of-flight method



Broad applicability:

- Temperature change by venting, collector movement, clouds [2]
- Validated for all common operational conditions (temperate, mass flow) [2]

Venting/Preheating

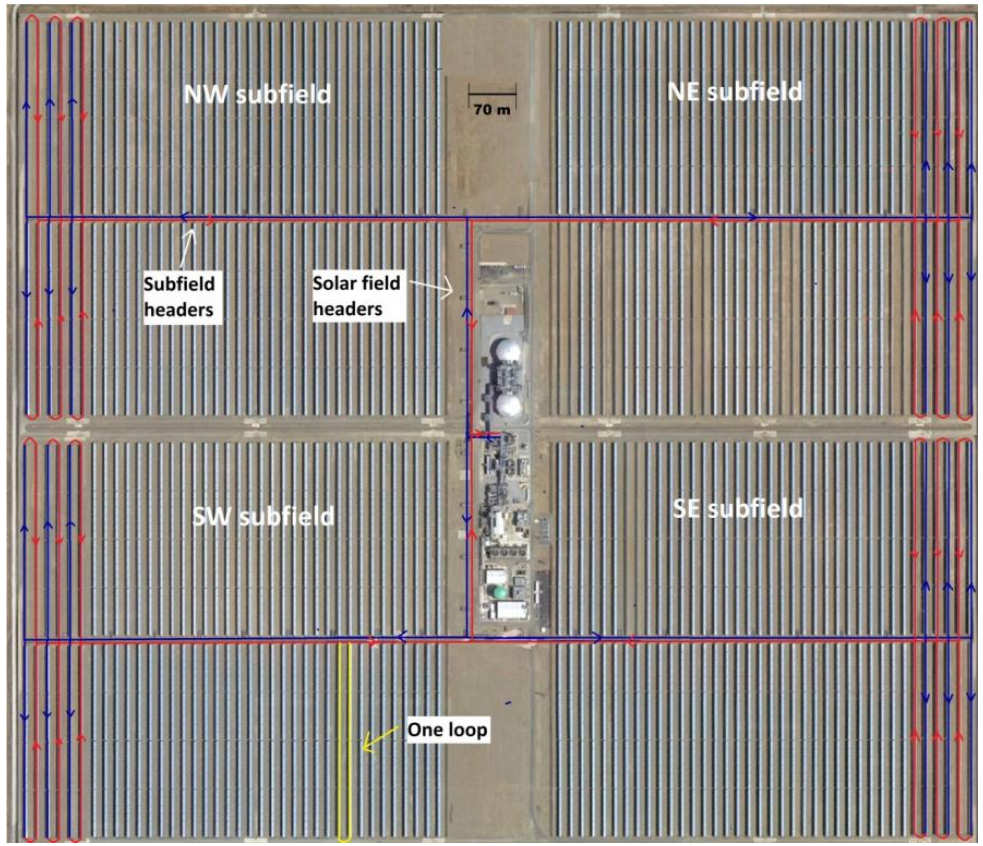
Focusing/Defocusing

Passing Clouds

[2] Kraft et al. (2025): Experimental Demonstration of a mass flow determination in Concentrated solar systems via collector defocusing using Time-of-Flight method. In Solar Energy.

What data was used for the analysis?

Reference plant and dataset



[3]

Reference Plant basic data:

Direction:	**Southern Spain**
Turbine capacity:	**50 MW**
Solar field:	**4 subfields, 152 loops**

Dataset:

Data range:	**16 consecutive days in Sept. 2019**
Resolution (temporal):	**< 10s**
Resolution (spatial):	**5 temperature sensors per loop (4+1)**
	1 mass flow meter per subfield

[3] Rohani, Shahab (2015): Modelling, Simulation and Data Validation of a Solar Thermal Parabolic Trough Plant with Storage.

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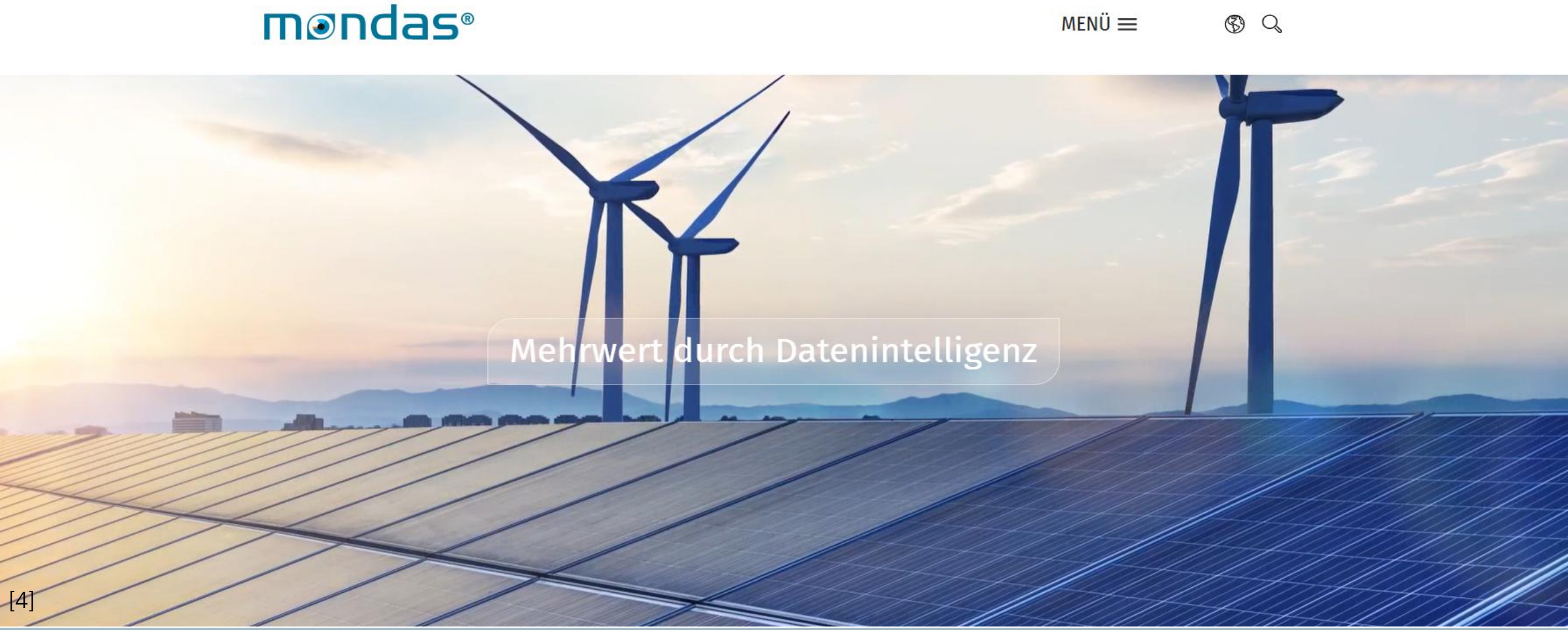
How is the mass flow measurement automized?

Mondas IoT-platform



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[4] www.mondas-iot.com

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Mondas IoT-platform

mondas®

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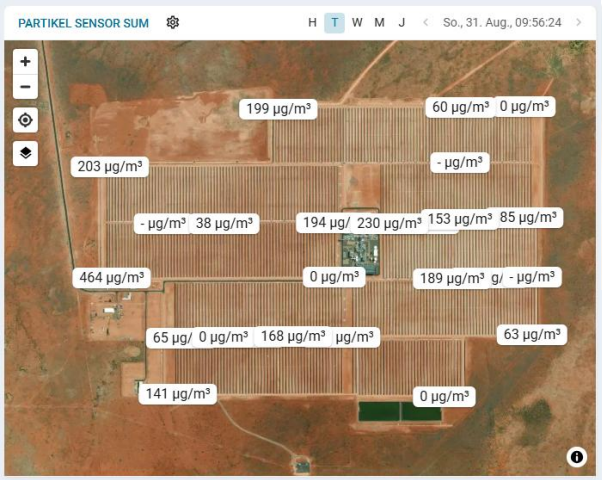

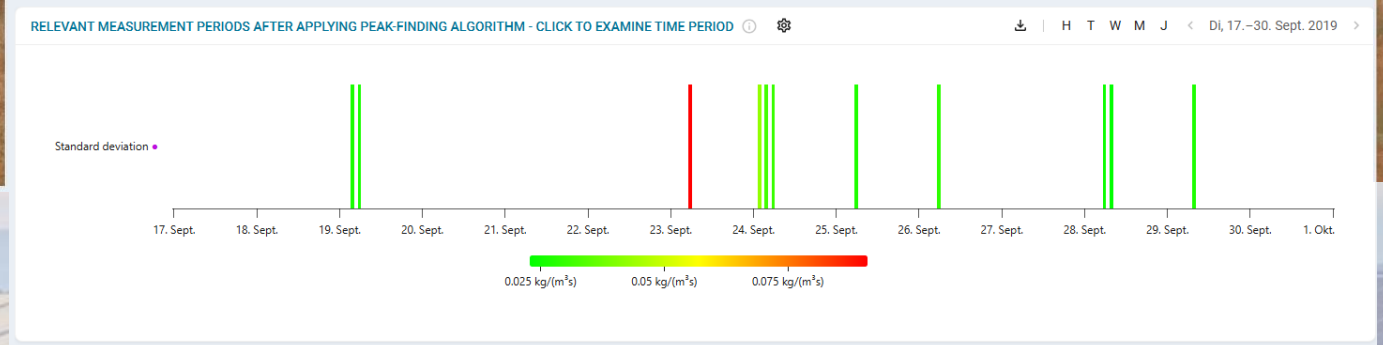

MASSFLOW DISTRIBUTION LEFT SIDE - DEVIATION OF MEAN FIELD FLOW [%]

X - Pos

L-05	L-07	L-09	L-11	L-13	L-15	L-17	L-19	L-21	L-23	L-25	L-27	L-29	L-31	L-33
3,4	2,0	1,7	0,2	-0,4	0,5	-3,0	-3,0	-3,9	-0,1	-3,3	-6,5	-5,6	-4,7	-3,6
2,8	1,7	2,2	1,0	2,2	-2,5	-1,8	-2,3	-4,7	-3,4	-1,4	-5,3	-3,0	-2,3	-6,1
2,9	2,5	-2,1	1,4	-1,1	0,1	-4,4	-2,8	-5,2	-4,0	-3,8	-4,9	-8,3	-1,3	-6,5
-4,8	-1,5	-11,5	-10,1	-10,6	-12,0	-8,0	-3,4	-4,3	-2,4	-4,0	-6,3	-10,4	-10,7	-9,0

MASSFLOW DISTRIBUTION RIGHT SIDE - DEVIATION OF MEAN FIELD FLOW [%]

X - Pos

R-06	R-08	R-10	R-12	R-14	R-16	R-18	R-20	R-22	R-24	R-26	R-28	R-30	R-32	R-34
-2,4	-1,3	-2,2	0,3	-0,4	0,6	1,3	0,1		3,2	3,1	4,1	2,2	-1,4	2,8
-4,3	-3,1	-0,8	-1,9	-1,4	-3,6	-0,9	-4,2	1,7	0,8	5,3	5,3	4,2	5,3	6,1
11,4	9,2	10,6	10,9	3,9	11,7	10,0	10,2	11,0	14,1	11,9	10,5	12,6	11,5	6,8
4,2	3,9	-2,2	-10,1	1,8	3,5	-1,0	-0,3	9,9	5,0	7,9	9,9	8,6	9,8	9,3

[4]

[4] www.mondas-iot.com

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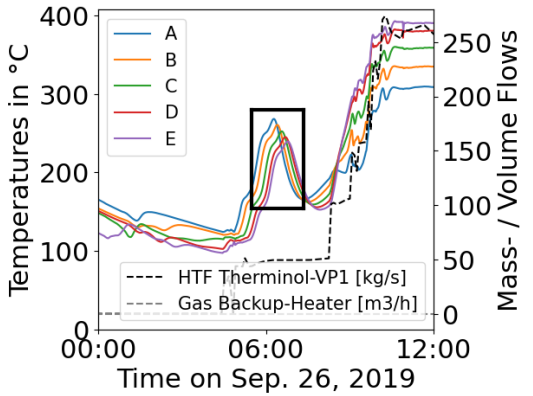
How is the mass flow measurement automized?

Method

Automatization on Mondas IoT platform in multiple steps:

- Detection of potential thermal step responses via peak finding algorithm
- Identification and exclusion of hydraulically locked loops/ unfulfilled conditions
- Calculation of mass flow distribution in solar field (incl. std deviation)



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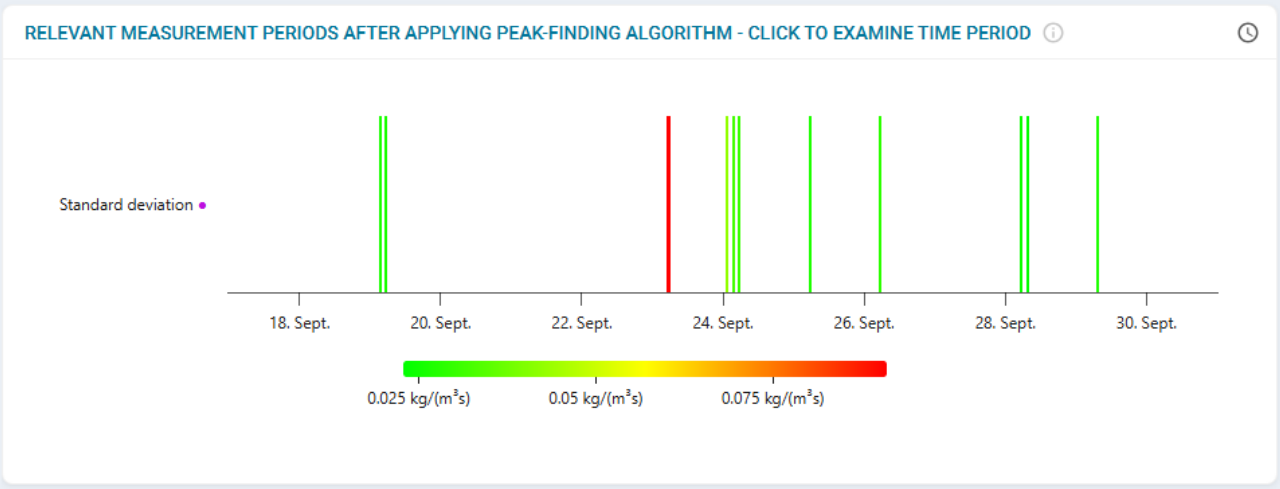

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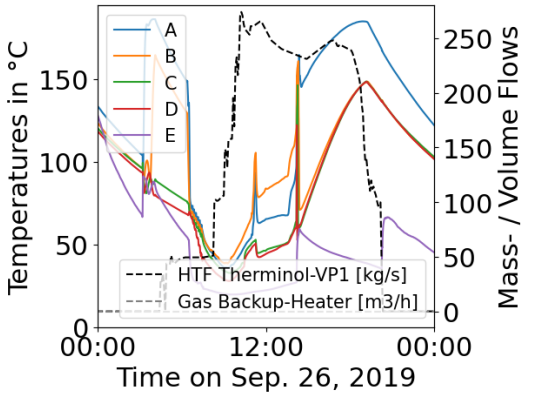

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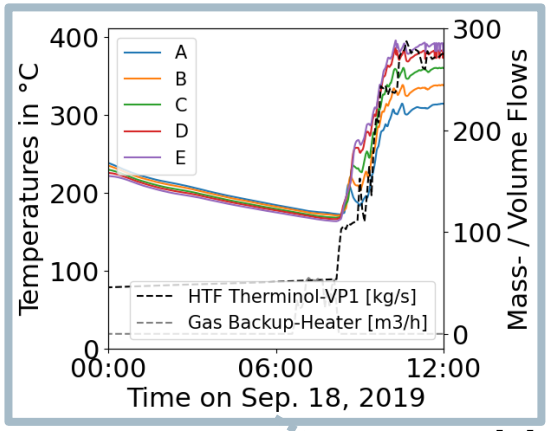

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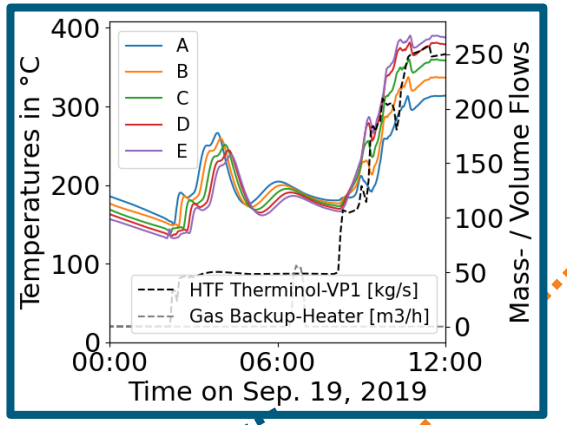

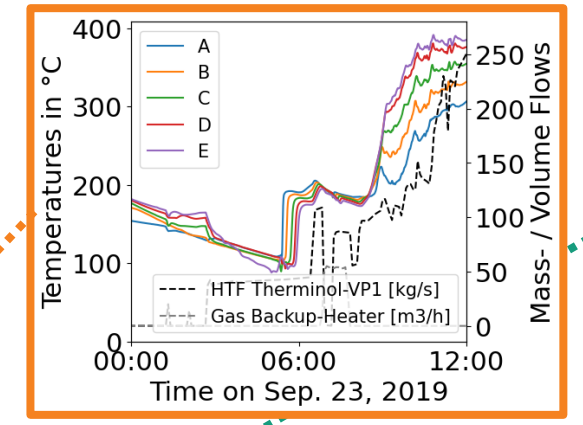

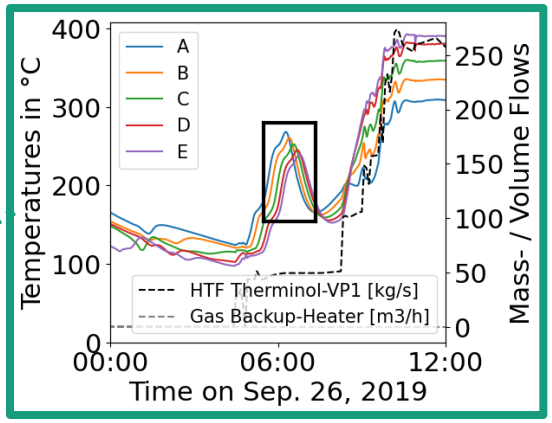

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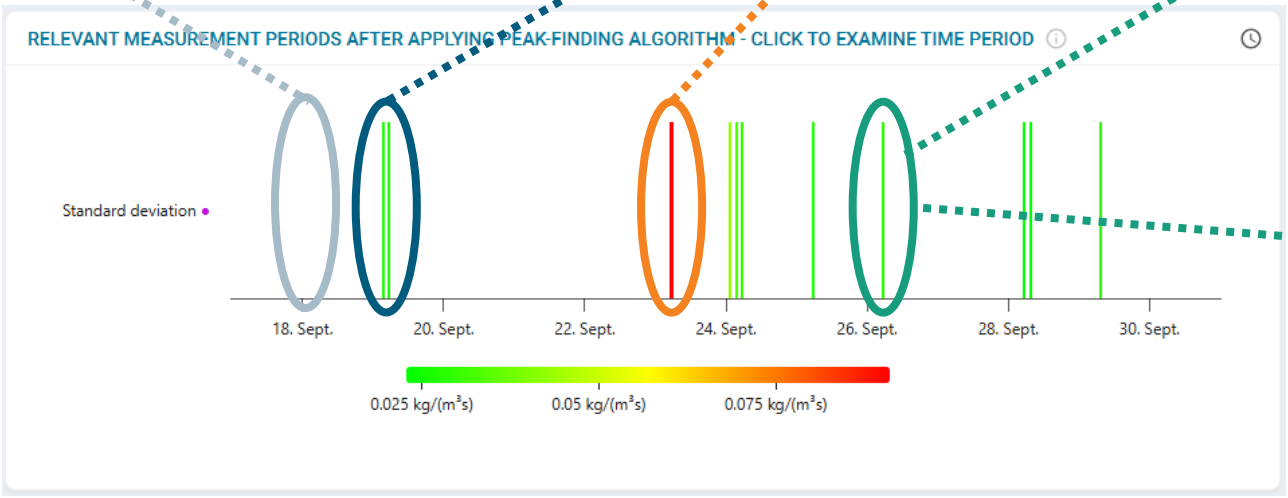

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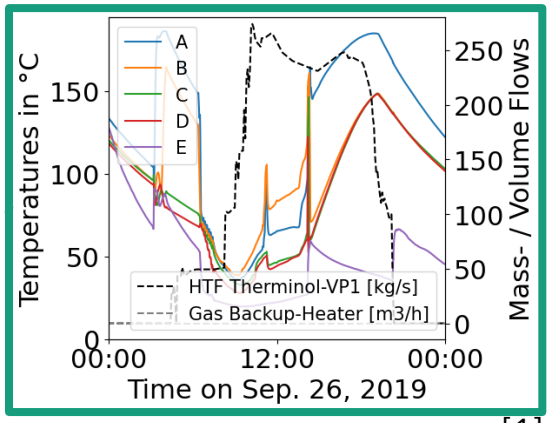

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[1] Kraft et al. (2024): Mass Flow Distribution Measurement in Concentrated Solar Power Plants via Thermal Time-of-Flight Method. In Solar Energy.
[4] www.mondas-iot.com

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How is the mass flow measurement automized?

Results

MASSFLOW DISTRIBUTION LEFT SIDE - DEVIATION O...

X - Pos

L-11	L-13	L-15	L-17	L-19	L-21	L-23	L-25	L-27
0,2	-0,4	0,5	-3,0	-3,0	-3,9	-0,1	-3,3	-6,5
1,0	2,2	-2,5	-1,8	-2,3	-4,7	-3,4	-1,4	-5,3
1,4	-1,1	0,1	-4,4	-2,8	-5,2	-4,0	-3,8	-4,9
-10,1	-10,6	-12,0	-8,0	-3,4	-4,3	-2,4	-4,0	-6,3

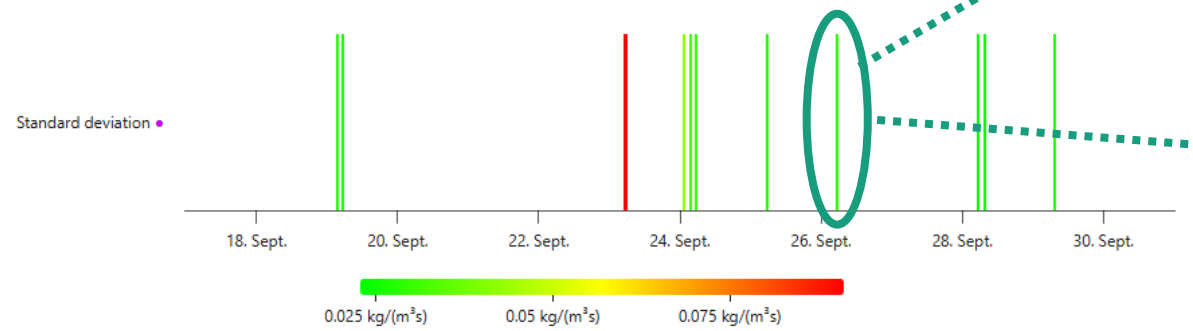
MASSFLOW DISTRIBUTION RIGHT SIDE - DEVIATION ...

X - Pos

R-12	R-14	R-16	R-18	R-20	R-22	R-24	R-26	R-28
0,3	-0,4	0,6	1,3	0,1		3,2	3,1	4,1
-1,9	-1,4	-3,6	-0,9	-4,2	1,7	0,8	5,3	5,3
10,9	3,9	11,7	10,0	10,2	11,0	14,1	11,9	10,5
-10,1	1,8	3,5	-1,0	-0,3	9,9	5,0	7,9	9,9

[4]

RELEVANT MEASUREMENT PERIODS AFTER APPLYING PEAK-FINDING ALGORITHM - CLICK TO EXAMINE TIME PERIOD



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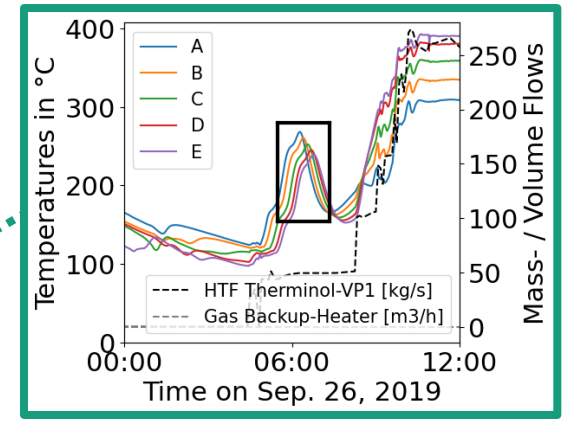

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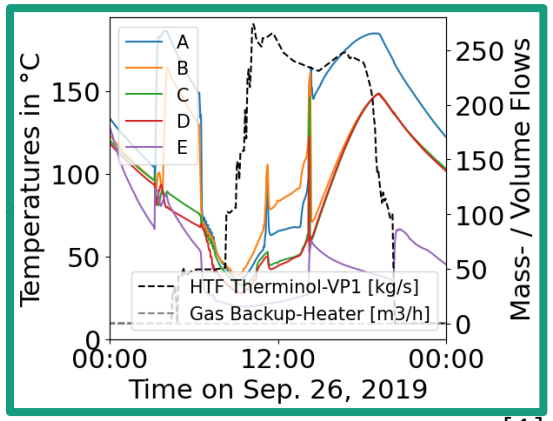

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[4] www.mondas-iot.com

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Results

MASSFLOW DISTRIBUTION LEFT SIDE - DEVIATION O...

X - Pos

L-11	L-13	L-15	L-17	L-19	L-21	L-23	L-25	L-27
0,2	-0,4	0,5	-3,0	-3,0	-3,9	-0,1	-3,3	-6,5
1,0	2,2	-2,5	-1,8	-2,3	-4,7	-3,4	-1,4	-5,3
1,4	-1,1	0,1	-4,4	-2,8	-5,2	-4,0	-3,8	-4,9
-10,1	-10,6	-12,0	-8,0	-3,4	-4,3	-2,4	-4,0	-6,3

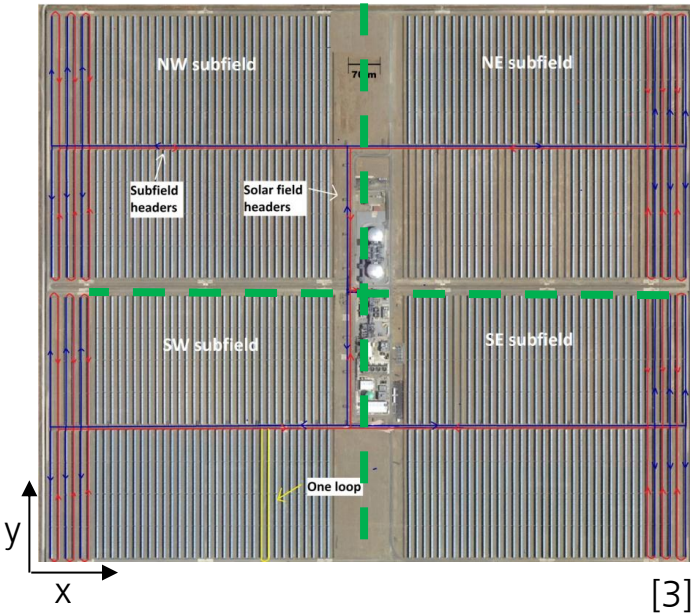
MASSFLOW DISTRIBUTION RIGHT SIDE - DEVIATION ...

X - Pos

R-12	R-14	R-16	R-18	R-20	R-22	R-24	R-26	R-28
0,3	-0,4	0,6	1,3	0,1		3,2	3,1	4,1
-1,9	-1,4	-3,6	-0,9	-4,2	1,7	0,8	5,3	5,3
10,9	3,9	11,7	10,0	10,2	11,0	14,1	11,9	10,5
-10,1	1,8	3,5	-1,0	-0,3	9,9	5,0	7,9	9,9

y
x

[4]



[3]

[4] www.mondas-iot.com
[3] Rohani, Shahab (2015): Modelling, Simulation and Data Validation of a Solar Thermal Parabolic Trough Plant with Storage.

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How is the mass flow measurement automized?

Results and validation

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X - Pos

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0,2	-0,4	0,5	-3,0	-3,0	-3,9	-0,1	-3,3	-6,5
1,0	2,2	-2,5	-1,8	-2,3	-4,7	-3,4	-1,4	-5,3
1,4	-1,1	0,1	-4,4	-2,8	-5,2	-4,0	-3,8	-4,9
-10,1	-10,6	-12,0	-8,0	-3,4	-4,3	-2,4	-4,0	-6,3

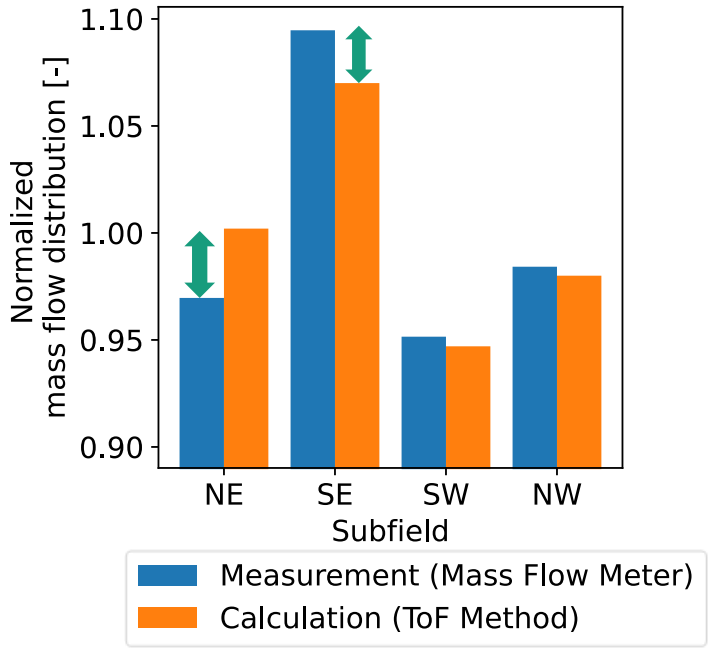
MASSFLOW DISTRIBUTION RIGHT SIDE - DEVIATION ...

X - Pos

R-12	R-14	R-16	R-18	R-20	R-22	R-24	R-26	R-28
0,3	-0,4	0,6	1,3	0,1		3,2	3,1	4,1
-1,9	-1,4	-3,6	-0,9	-4,2	1,7	0,8	5,3	5,3
10,9	3,9	11,7	10,0	10,2	11,0	14,1	11,9	10,5
-10,1	1,8	3,5	-1,0	-0,3	9,9	5,0	7,9	9,9

y
x

[4]



[1]

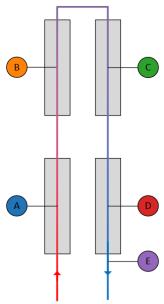
→ The automated ToF method determines the mass flow distribution through the solar field, with **deviations** between calculated (ToF Method) and measured (Mass flow meters) mass flow **below 5%**

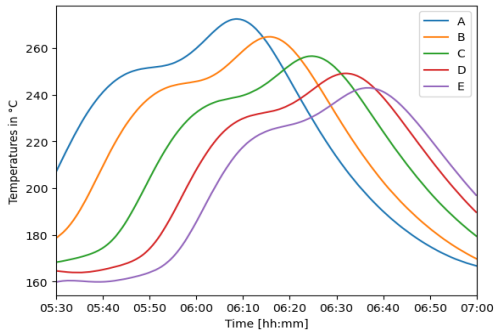
→ Knowledge of mass flow distribution offers high potential to **increase total plant efficiency** by detection of inefficient Loops/SCAs (e.g., due to **vacuum losses** or **optical losses** [5])

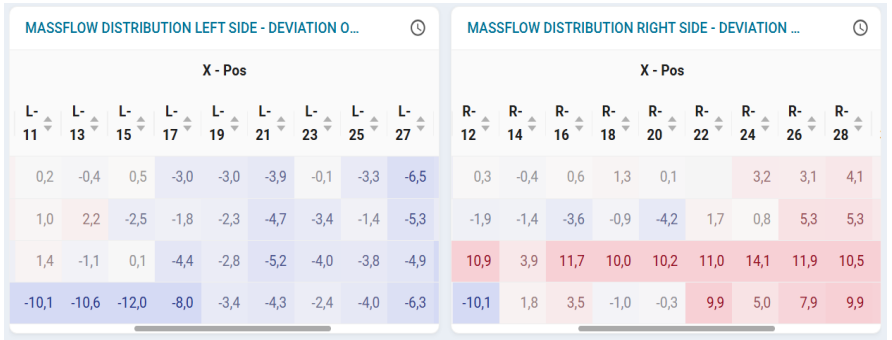
[4] www.mondas-iot.com
[1] Kraft et al. (2024): Mass Flow Distribution Measurement in Concentrated Solar Power Plants via Thermal Time-of-Flight Method. In Solar Energy.
[2] Kraft et al. (2024): Vacuum Loss Detection of PTC in CSP Plants via Temperature-Sensors. In SolarPACES Conf Proc 2.

Conclusion

- A **fully automated non-invasive and innovative mass flow distribution measurement** of a solar field in a commercial operating concentrated solar systems was presented to **enhance operation and maintenance**
- Measurement bases on **time-of-flight method,** where sudden changes of heat transfer fluid temperature are analyzed
- Data **preprocessing, filtering, analysis and visualization** is done automatically within the **Mondas IoT platform**
- Validation of mass flow distribution measurement in multiple recent publications, with **deviations of less than 5%** between measured and calculated mass flow → Solar Energy (2024/25)
- Usage of automated mass flow distribution measurement offers **great potential to enhance the overall efficiency** of concentrating solar thermal systems as it is **safe, simple, cost effective and completely non-invasive**







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