COMPARISON OF ADVANCED PARAMETER IDENTIFICATION METHODS FOR LINEAR FRESNEL COLLECTORS

Application to Measurement Data

Linear Fresnel collector at The Cyprus Institute

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SolarPACES 2020

September 30, 2020

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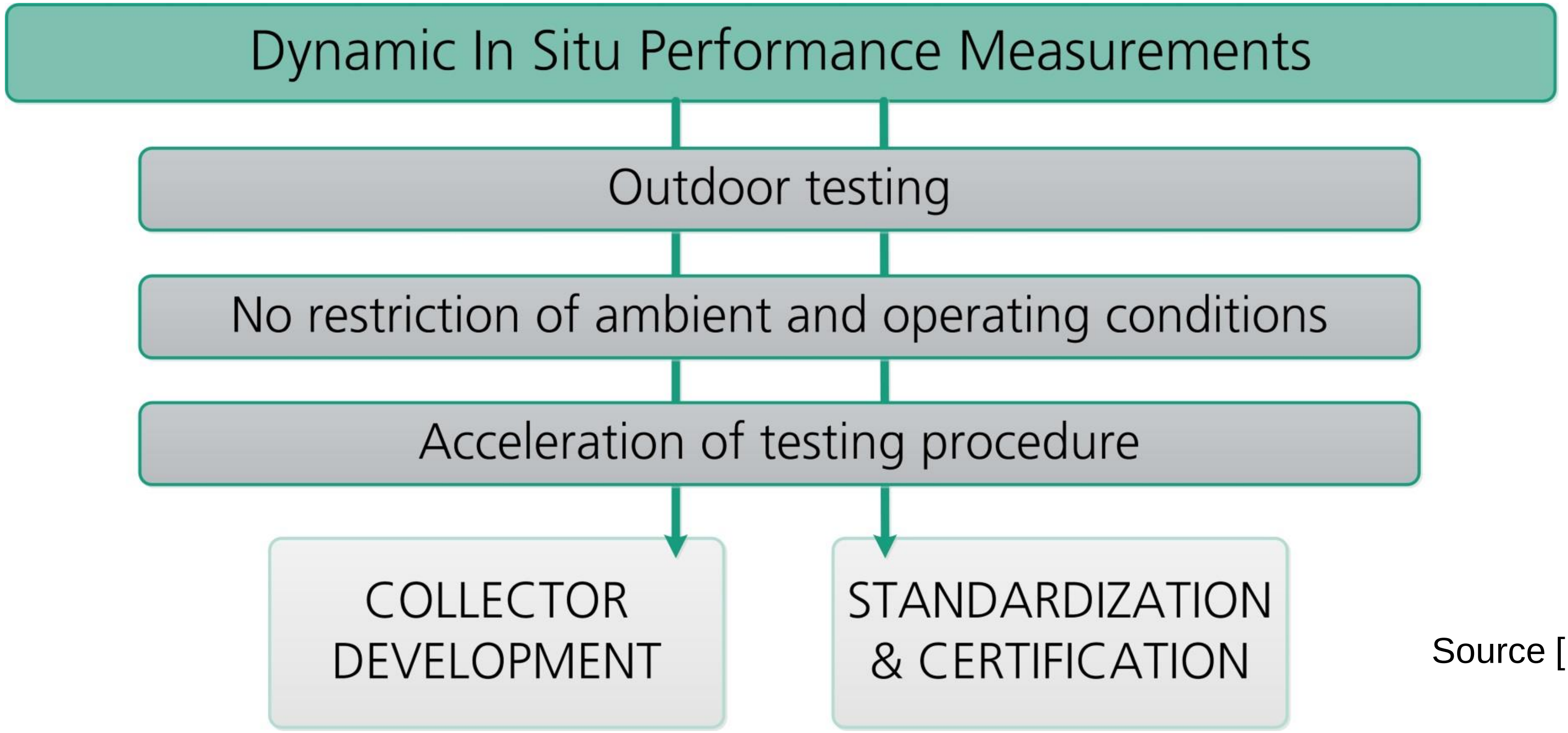
Motivation



Dynamic In Situ Performance Measurements

Outdoor testing

No restriction of ambient and operating conditions

Acceleration of testing procedure

COLLECTOR DEVELOPMENT

STANDARDIZATION & CERTIFICATION

Source [1,2]

- Identification of main collector parameters regarding optical efficiency and thermal losses
- Different methodologies by Fraunhofer ISE and The Cyprus Institute

➢ Quantitative comparison for different variations with different identification parameters

OUTLINE

- Motivation
- Test facility and sensors
- Measurement data set
- Parameter identification methodologies
- Application to test facility
    - Identified parameters
    - Quality of temperature fit
    - Comparison of IAM profiles: ray tracing vs identification with ParaID
- Conclusion
- References

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Test facility and sensors

Linear Fresnel collector at the Cyprus Institute

- In operation since 2016, for air-conditioning of Novel Technologies Laboratory
- North-South aligned
- 288 mirrors, 184.32m^2, driven by 72 DC motors
- Duratherm 450 as HTF, operated up to 180°C
- 32m vacuum glass absorber (8 units)

LFR and the Novel Technologies Laboratory

Weather station Davis Vantage Pro 2
Pyrheliometer, LP Pyhre 16 AC

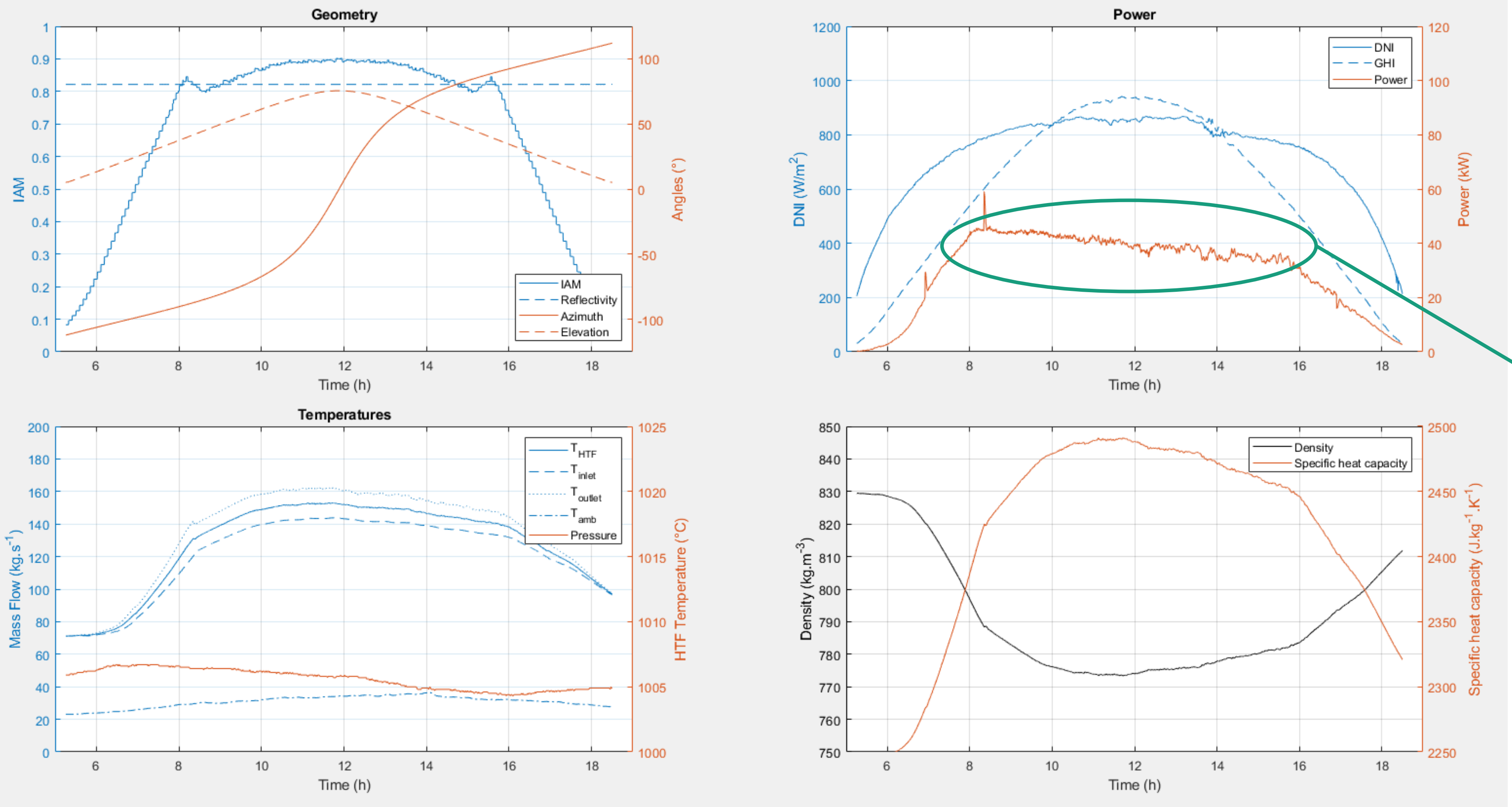
D&S 15R-USB
Reflectometry/Cleanliness at 660nm

Endress + Hauser
Vortex flowmeter

PT100 TC
immersed in flow

Measurement data set

50+ registered days in 2018 and 2019, 15-30s time steps



Nearly constant DNI
Decreasing power

- → angle dependency of optical efficiency
- → Can be observed on the other registered days

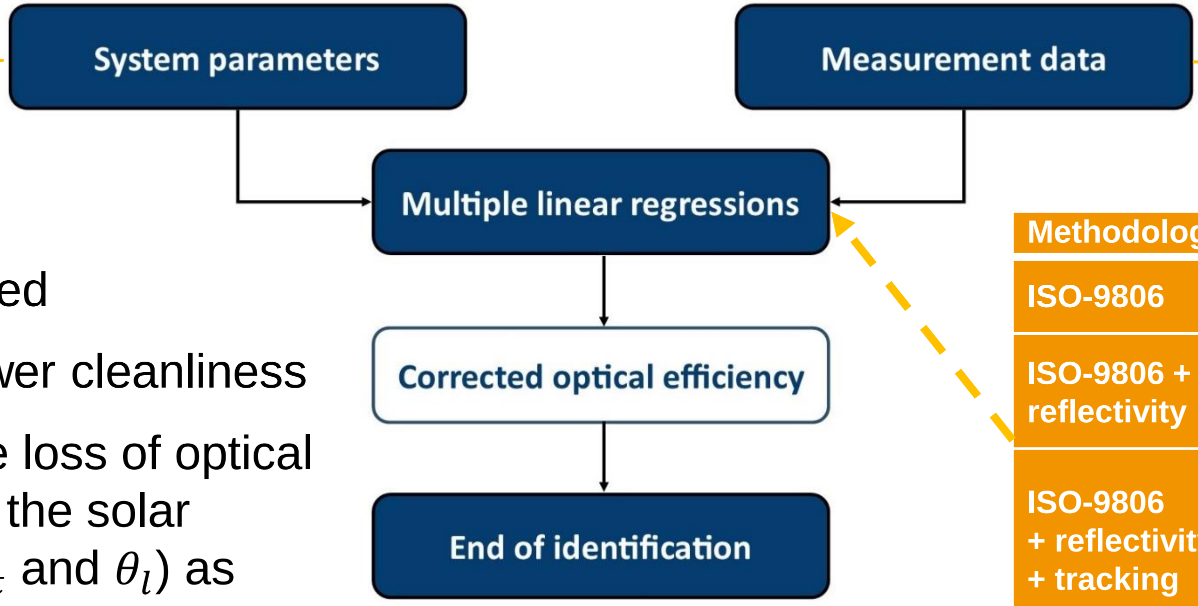
Exemplary day
July 20, 2019

Parameter identification methodologies

RealTrackEff by Cyprus Institute [4]

- HTF thermal properties
- Ray tracing IAMs

- T_{in}, T_{out}, $\dot{m}$ (collector)
- T_{amb}, G_b (weather)
- ξ_{clean}, Reflectometry (cleanliness) on 32 points on the collector



System parameters

Measurement data

Multiple linear regressions

Corrected optical efficiency

End of identification

⇒ Offline IAMs are unchanged

⇒ Reflectometry induces lower cleanliness

⇒ The method considers the loss of optical efficiency as a function of the solar angles on the collector (θ_t and θ_l) as part of tracking errors

Methodology	Optical efficiency
ISO-9806	$\xi_{clean}(t) = 1$ $\rho_{track}(t) = 1$
ISO-9806 + reflectivity	$\xi_{clean}(t)$, as per reflectometry measurements at 660 nm $\rho_{track}(t) = 1$
ISO-9806 + reflectivity + tracking error	$\xi_{clean}(t)$, as per reflectometry measurements at 660 nm $\rho_{track}(t) = \sum_{k=0}^{n} \sum_{l=0}^{n} c_{k,l} \cdot \theta_t{}^k \cdot \theta_l{}^l$ $(k + \mathrm{l} = n)$

Parameter identification methodologies

ParaID by Fraunhofer ISE [1, 2]

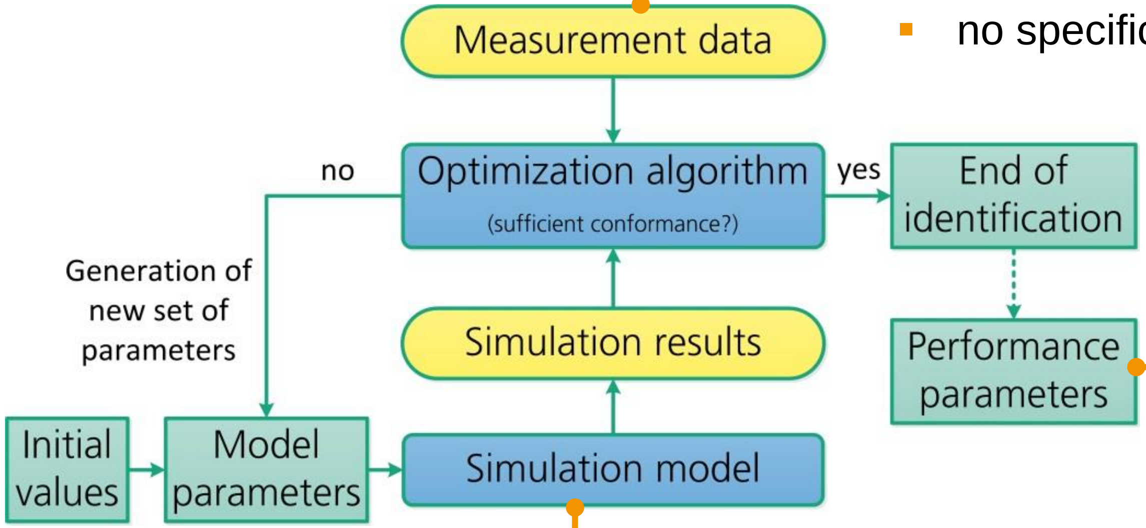
Testing Strategy:

- number of days > 8 for LFCs
- high level and range of temperatures
- spread incidence situation
- minimum DNI per angle bin
- no specific operating conditions

$\eta_{opt,0}$

heat loss

IAM



Discretization Approach:

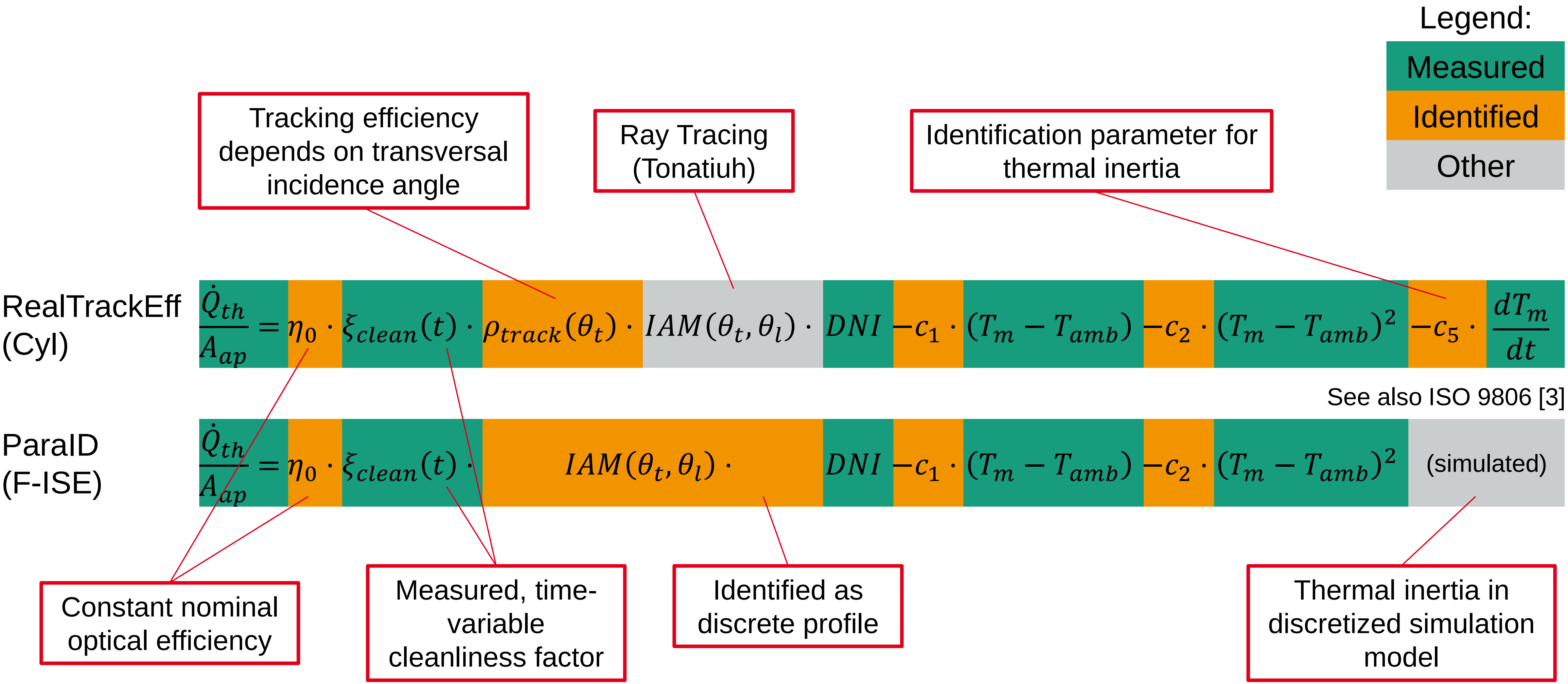
- plug-flow model
- in-house software ColSim

Confidence Computation:

- quality assessment of evaluation results
- bootstrapping procedure

Parameter identification methodologies

Comparison of identification equations



Legend:

- 🟩 Measured
- 🟧 Identified
- ⬜ Other

RealTrackEff (Cyl)

$$\frac{\dot{Q}_{th}}{A_{ap}} = \eta_0 \cdot \xi_{clean}(t) \cdot \rho_{track}(\theta_t) \cdot IAM(\theta_t, \theta_l) \cdot DNI - c_1 \cdot (T_m - T_{amb}) - c_2 \cdot (T_m - T_{amb})^2 - c_5 \cdot \frac{dT_m}{dt}$$

See also ISO 9806 [3]

ParaID (F-ISE)

$$\frac{\dot{Q}_{th}}{A_{ap}} = \eta_0 \cdot \xi_{clean}(t) \cdot IAM(\theta_t, \theta_l) \cdot DNI - c_1 \cdot (T_m - T_{amb}) - c_2 \cdot (T_m - T_{amb})^2$$ (simulated)

Tracking efficiency depends on transversal incidence angle

Ray Tracing (Tonatiuh)

Identification parameter for thermal inertia

Constant nominal optical efficiency

Measured, time-variable cleanliness factor

Identified as discrete profile

Thermal inertia in discretized simulation model

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Application to test facility

Identified parameters

ParaID

Methodology variation	$\eta_0 [\%]$	$HL_{115°C}$ $[W/m]$	RMS_T $[°C]$
Base case: η_0, c_1, c_2	32.7	192	2.24
+ Variable cleanliness ξ_{clean}	36.8	109	1.94
+ IAM identification	31.4	217	1.81
+ Variable cleanliness ξ_{clean} + IAM identification	32.0	110	1.48

RealTrackEff

Methodology variation	$\eta_0 [\%]$	$HL_{115°C}$ $[W/m]$	RMS_T $[°C]$
Base case: η_0, c_1, c_2	71.7	1777	4.59
+ Variable cleanliness ξ_{clean}	29.2	98	1.59
+ Variable cleanliness ξ_{clean} + tracking efficiency (n=1)		122	1.25
+ Variable cleanliness ξ_{clean} + tracking efficiency (n=2)		32	0.99

Length-specific heat losses:

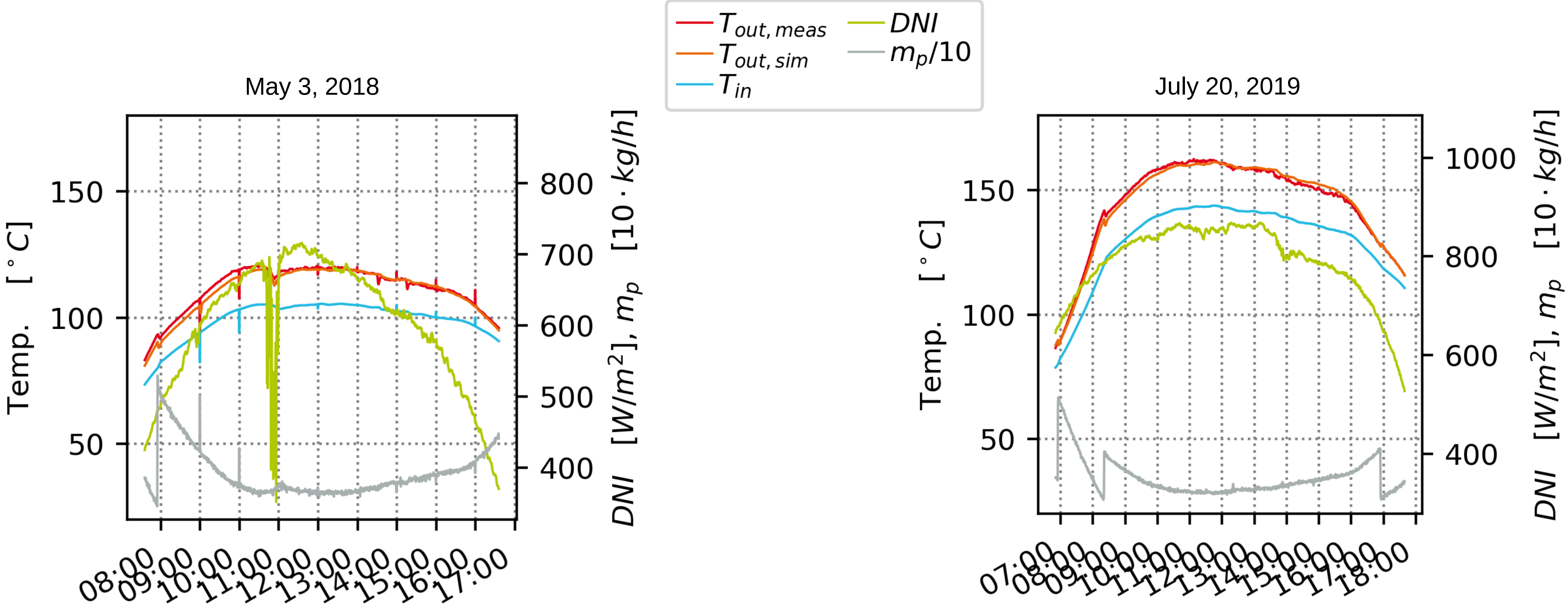
$$HL_{115°C}\left[\frac{W}{m}\right] = c_1 \cdot \frac{A_{ap}}{L_{coll}} \cdot (T_m - T_{amb}) + c_2 \cdot \frac{A_{ap}}{L_{coll}} \cdot (T_m - T_{amb})^2$$

with $T_m - T_{amb} = 115°\text{C}$

$$RMS_T = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(T_{meas,i} - T_{sim,i}\right)^2}$$

Application to test facility

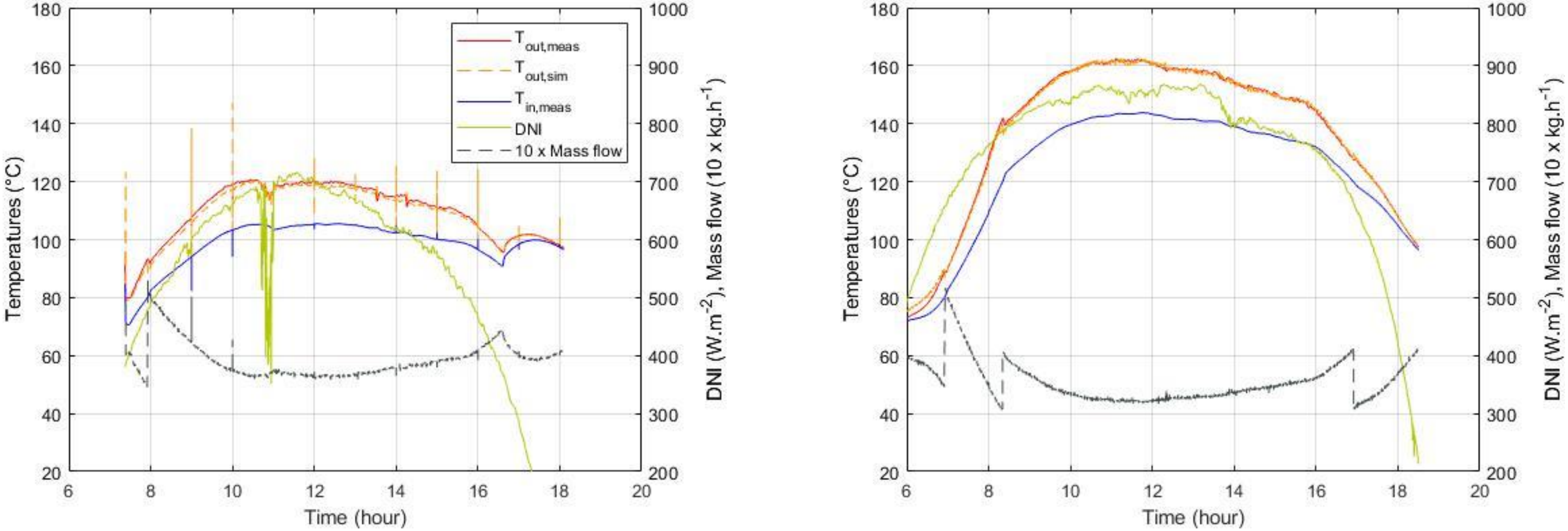
ParaID: quality of temperature fit



Time series for two selected days, for ParaID variation with variable cleanliness and IAM identification

Application to test facility

RealTrackEff: quality of temperature fit



May 3, 2018

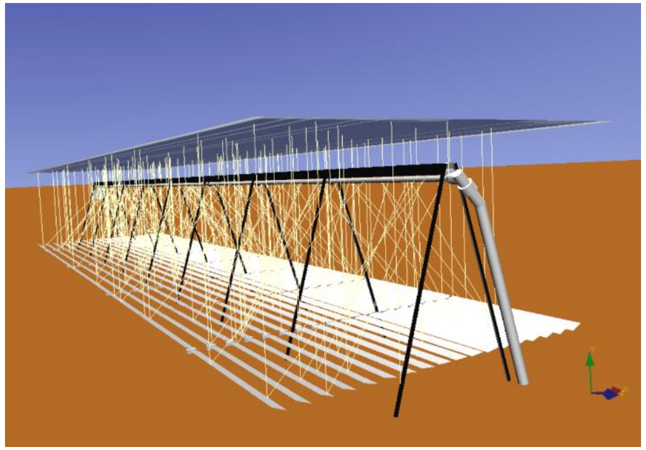
July 20, 2019

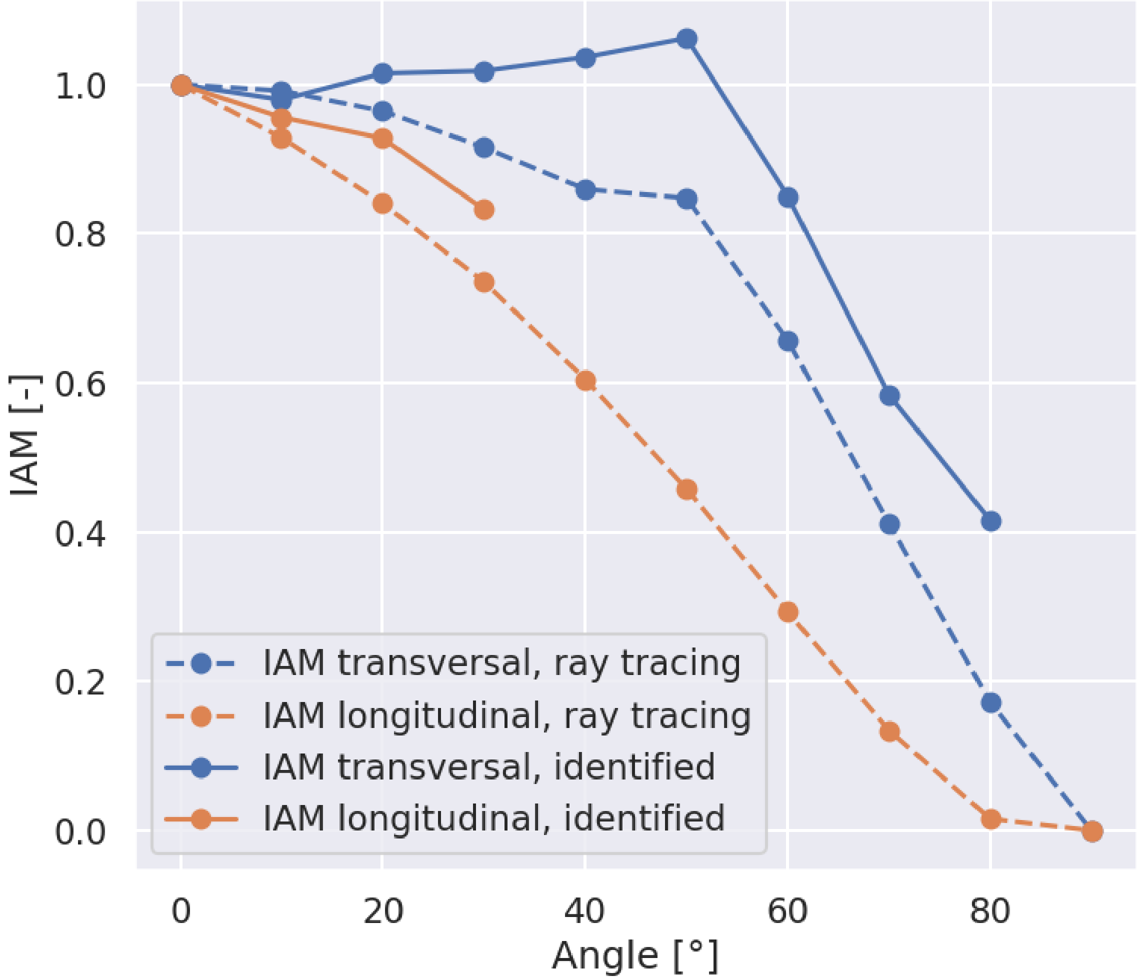
Time series for two selected days, for RealTrackEff variation with variable cleanliness and tracking efficiency (n=2)

Application to test facility

Comparison of IAM profiles: ray tracing vs identification with ParaID

- IAM identified for angle sections with sufficient measurement data
- ➢ Significant differences to ideal IAM from ray tracing





Conclusion

- Collector performance assessment based on dynamic, in-situ tests and parameter identification
- Consideration of cleanliness is crucial
- Real collector IAM might differ significantly from ideal ray tracing results (asymmetric profile)
- Tracking effect has to be taken into account, as tracking can’t be ideal and continuous

References

[1] Zirkel-Hofer, A. et al. (2018): Enhanced dynamic performance evaluation method of line-concentrating solar collectors. In: AIP Conference Proceedings SolarPACES 2017, Bd. 2033.

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[3] ISO 9806, 2013: Solar energy - Solar thermal collectors - Test methods.

[4] Montenon, Alaric & Tsekouras, Panagiotis & Tzivanidis, Christos & Bibron, Mathéou & Papanicolas, C.N.. (2019). Thermo-optical modelling of the linear Fresnel collector at the Cyprus institute. AIP Conference Proceedings. 2126. 100004. 10.1063/1.5117613.

[5] Zirkel-Hofer, Annie; Perry, Stephen; Kramer, Korbinian; Heimsath, Anna; Scholl, Stephan; Platzer, Werner (2018): Confidence interval computation method for dynamic performance evaluations of solar thermal collectors. In: *Sol Energy* 162, S. 585–596. DOI: 10.1016/j.solener.2018.01.041.

Thank you for your attention!

The research that led to these results has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreements No 823802 and No 731287

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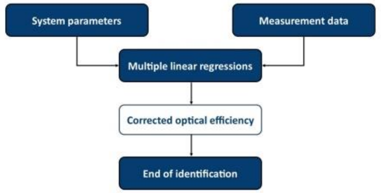

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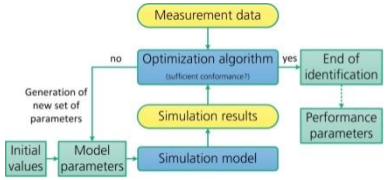
Corrected optical efficiency

End of identification



Measurement data

Optimization algorithm
(sufficient conformance?)

no

yes

End of identification

Generation of new set of parameters

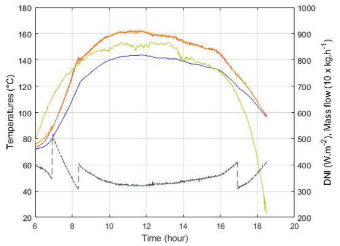
Simulation results

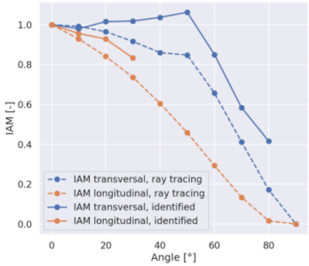
Performance parameters

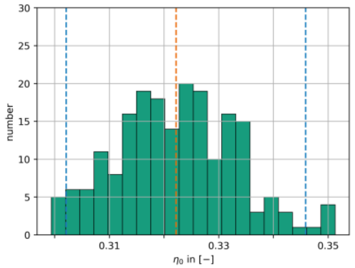
Initial values

Model parameters

Simulation model







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