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PV shading models with pvlib

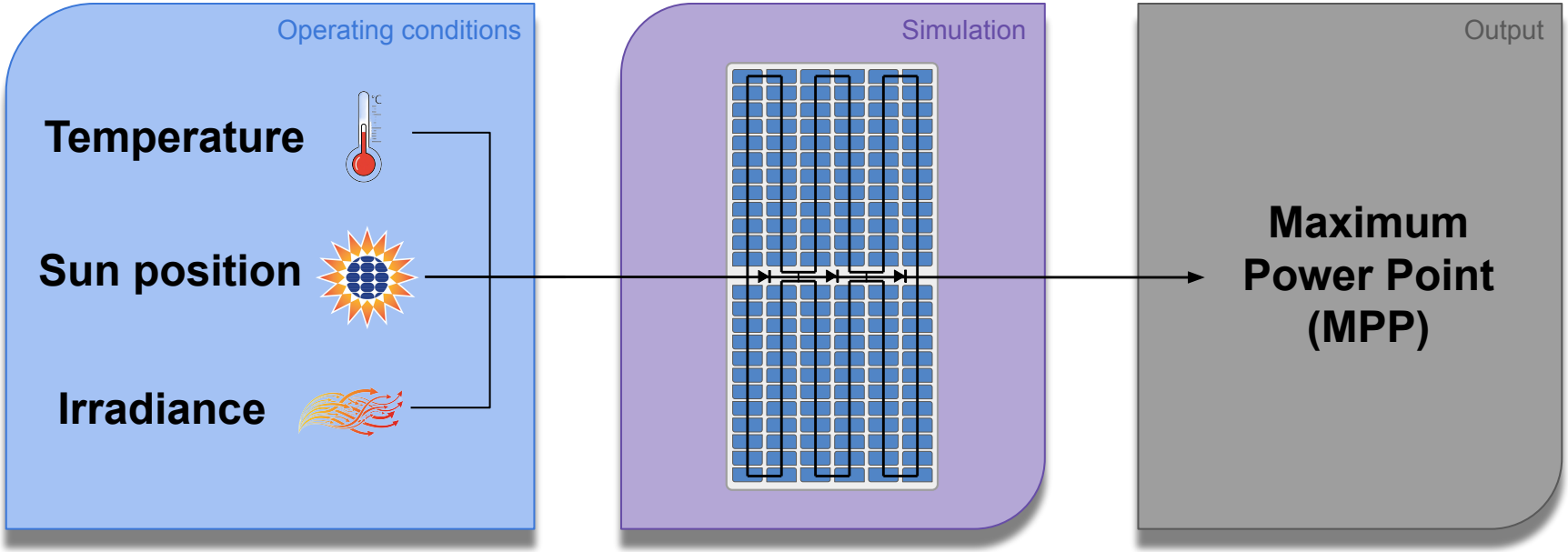
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Accelerating photovoltaic system simulations via statistical data aggregation

Adrián Blanco Aguiar

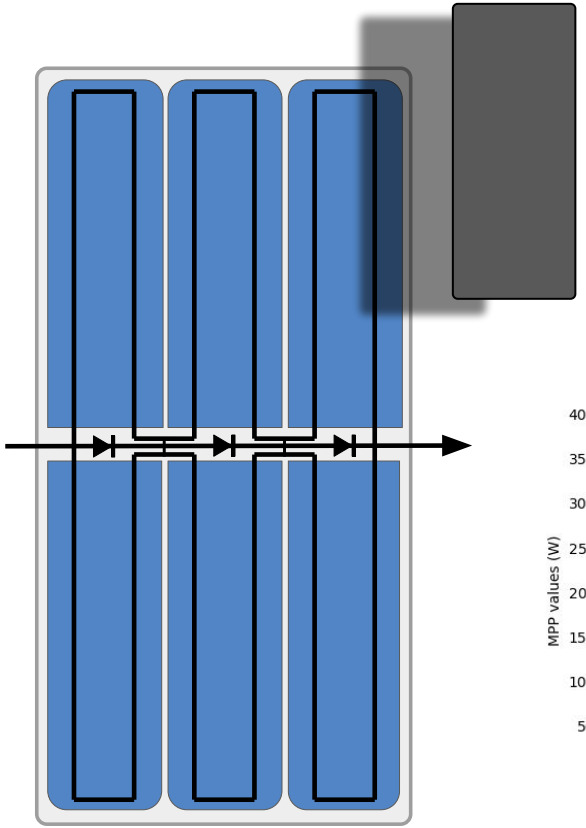
Simulation process

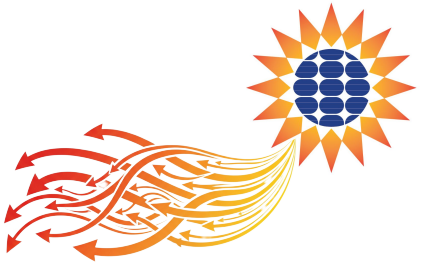
Hourly operating conditions



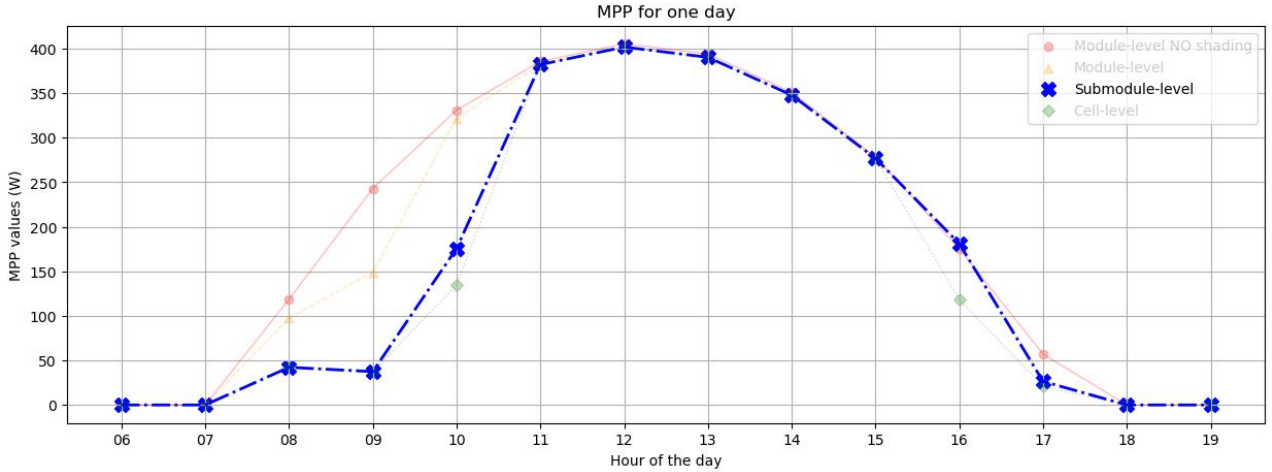
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Submodule-level





This is the one we use as the accurate reference method in our work!

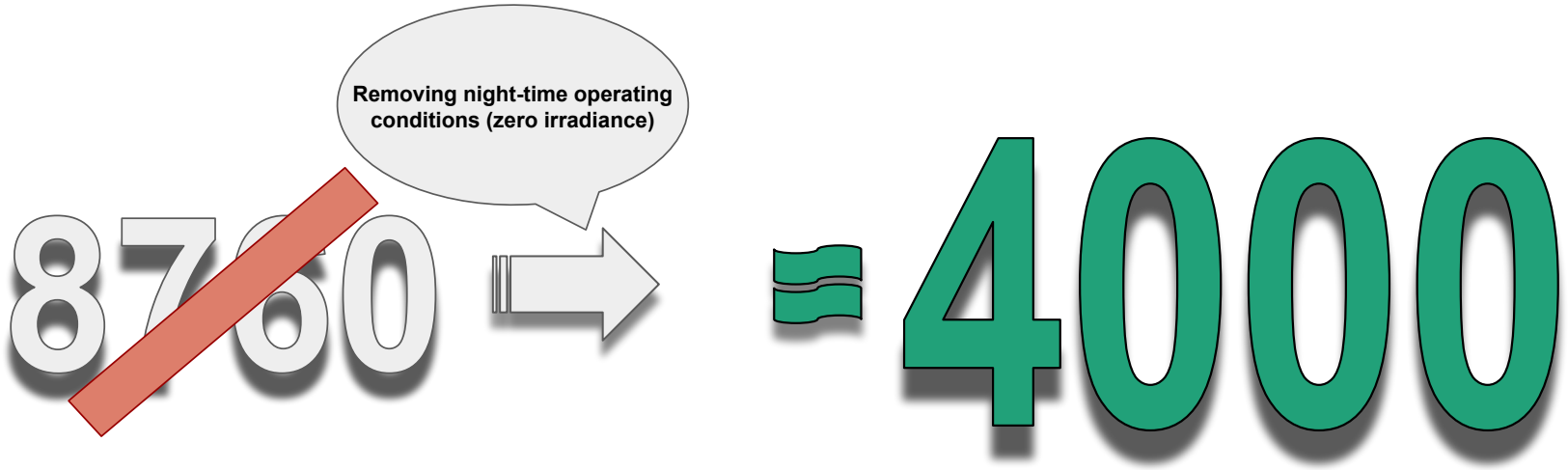


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8760

hourly operating conditions in a year!

Problem



hourly operating conditions in a year!

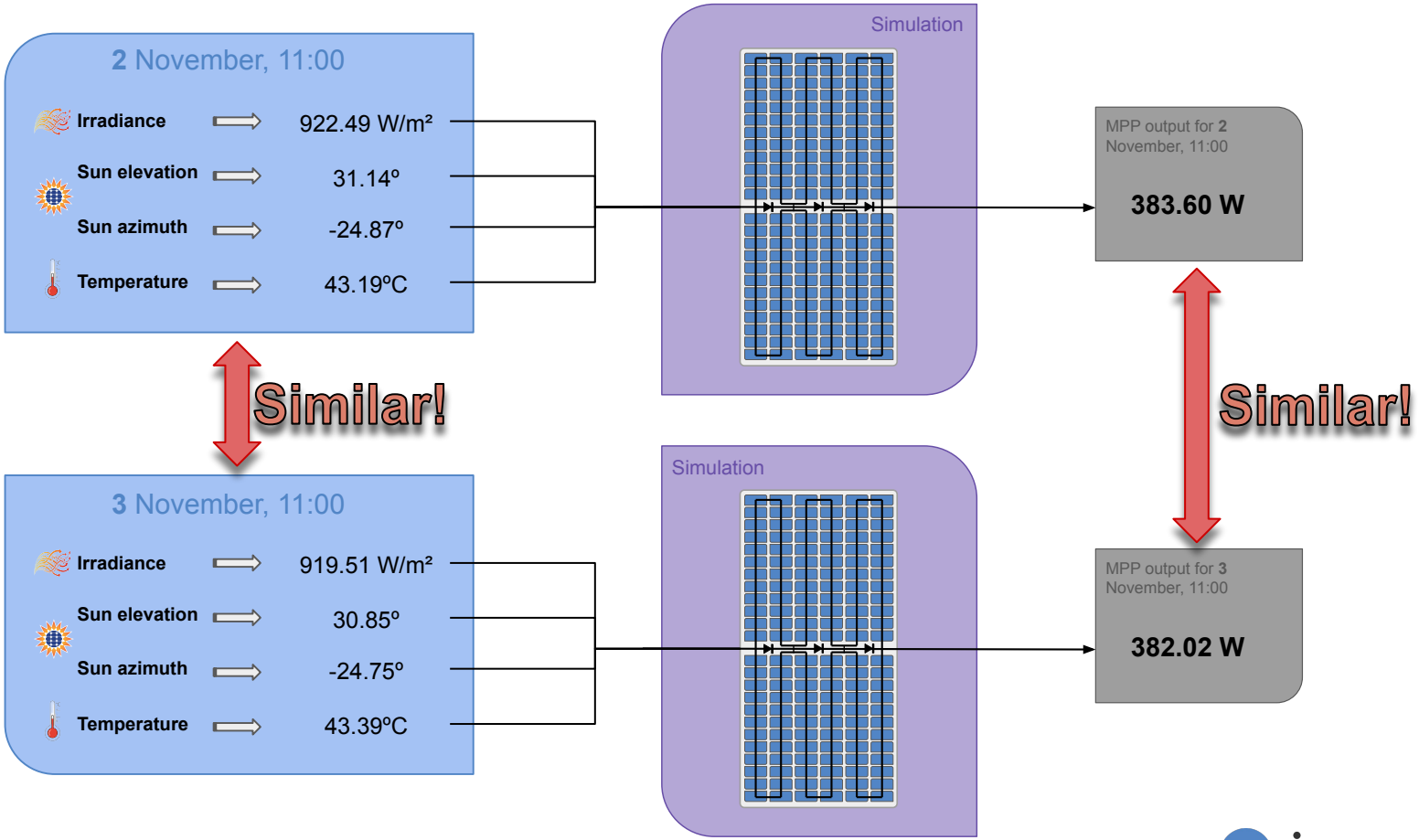
high computational cost

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4000

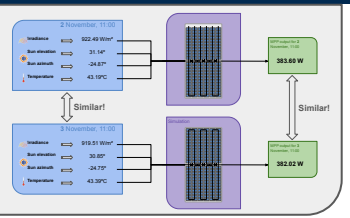
How do we reduce this number?

Similar operating conditions produce similar results



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Aggregation of similar operating conditions



Just one simulation!

2 November, 11:00

Irradiance	922.49 W/m²
Sun elevation	31.14°
Sun azimuth	-24.87°
Temperature	43.19°C

3 November, 11:00

Irradiance	919.51 W/m²
Sun elevation	30.85°
Sun azimuth	-24.75°
Temperature	43.39°C

Mean operating conditions

mean	921 W/m²
mean	31°
mean	-24.81°
mean	43.29°C

Simulation

MPP output

382.81 W

Real value:
383.60 W

MPP output for **2** November, 11:00

382.81 W

MPP output for **3** November, 11:00

382.81 W

Real value:
382.02 W

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Aggregation of similar operating conditions

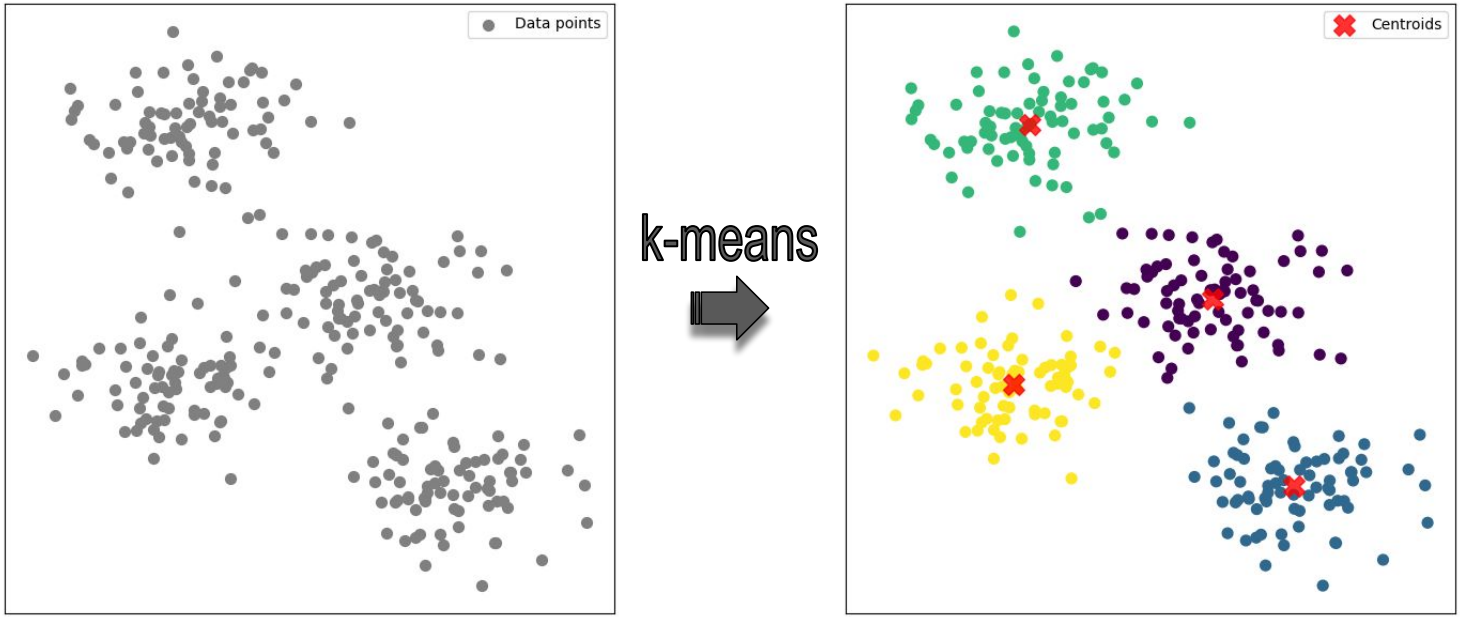
How do we automatically aggregate similar operating conditions?

k-means

Unsupervised machine learning algorithm for data segmentation (clustering)

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K-means algorithm



Centroids (✖) as new data points

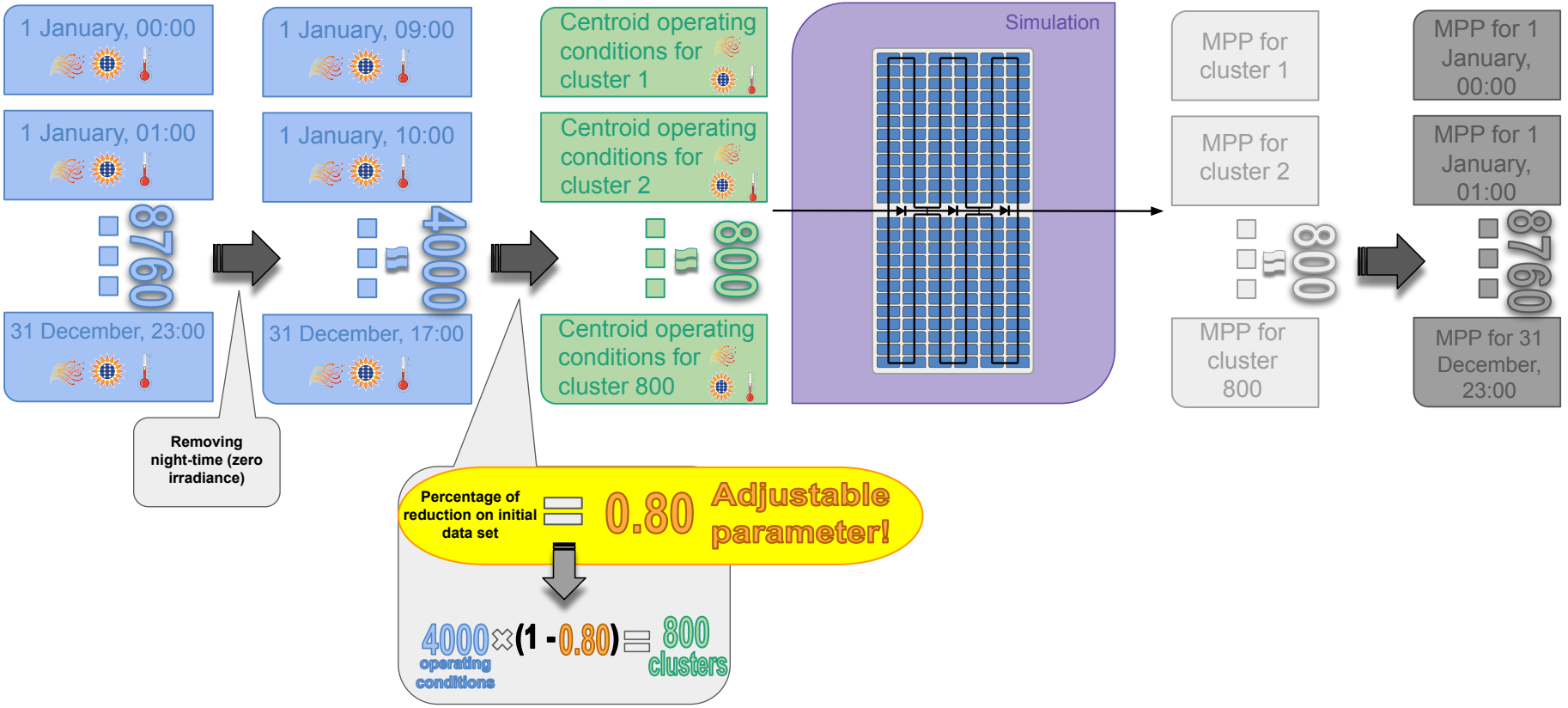
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Initial data aggregation approaches

- StraightForward Aggregation (SFA)
- Hierarchical Hourly Aggregation (HHA)

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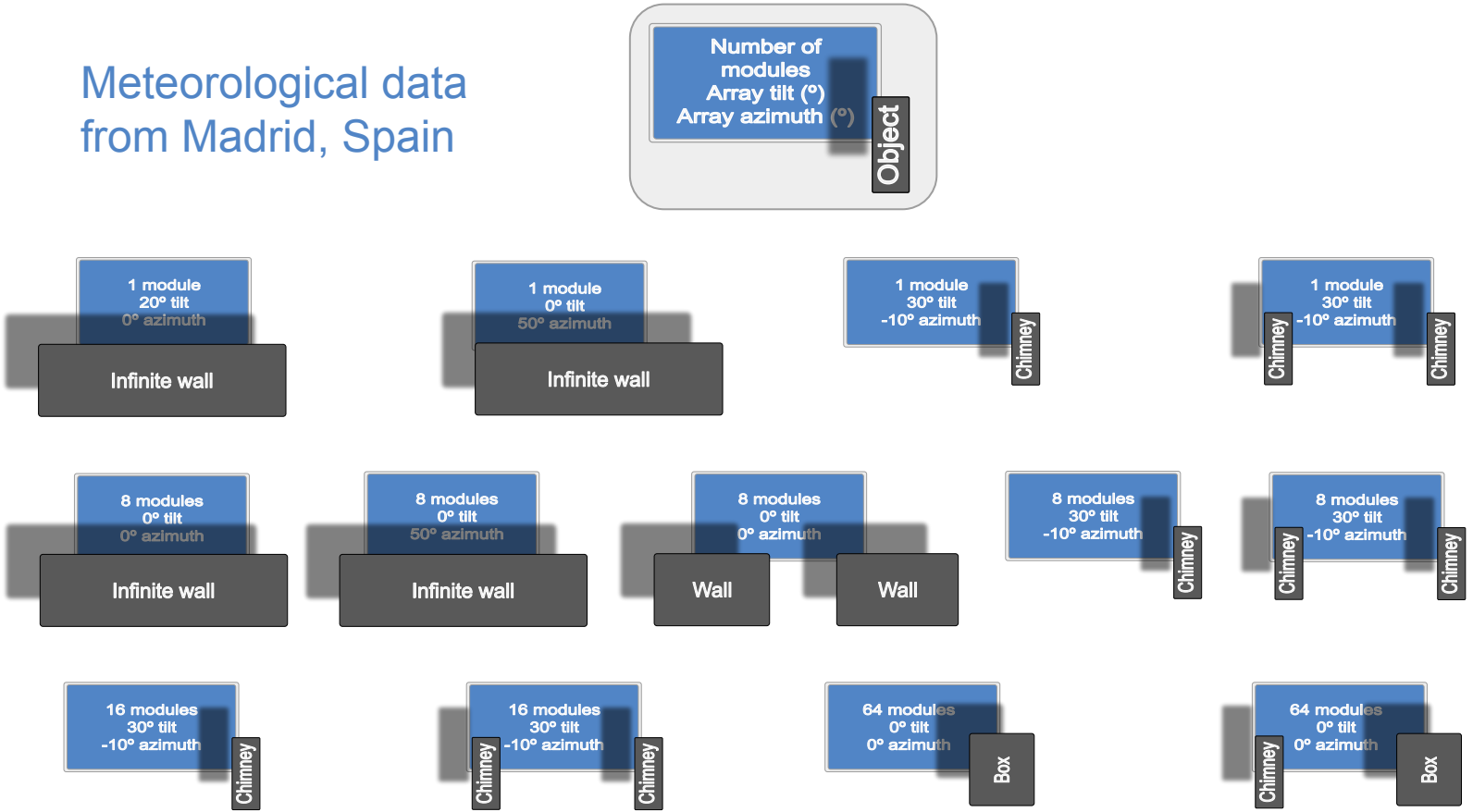
Straight-Forward Aggregation (SFA)



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Simulation scenarios for performance testing

Meteorological data
from Madrid, Spain

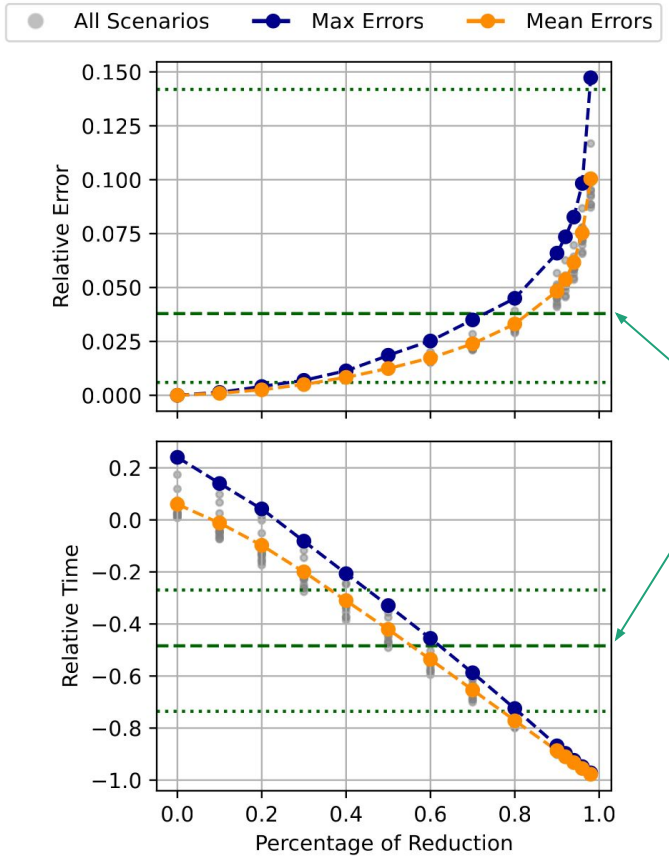


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SFA performance results

$$Relative\ Error = \frac{\sum \left| MPP_{new\ method} - MPP_{reference\ method} \right|}{\sum MPP_{reference\ method}}$$

$$Relative\ Time = \frac{time_{new\ method} - time_{reference\ method}}{time_{reference\ method}}$$



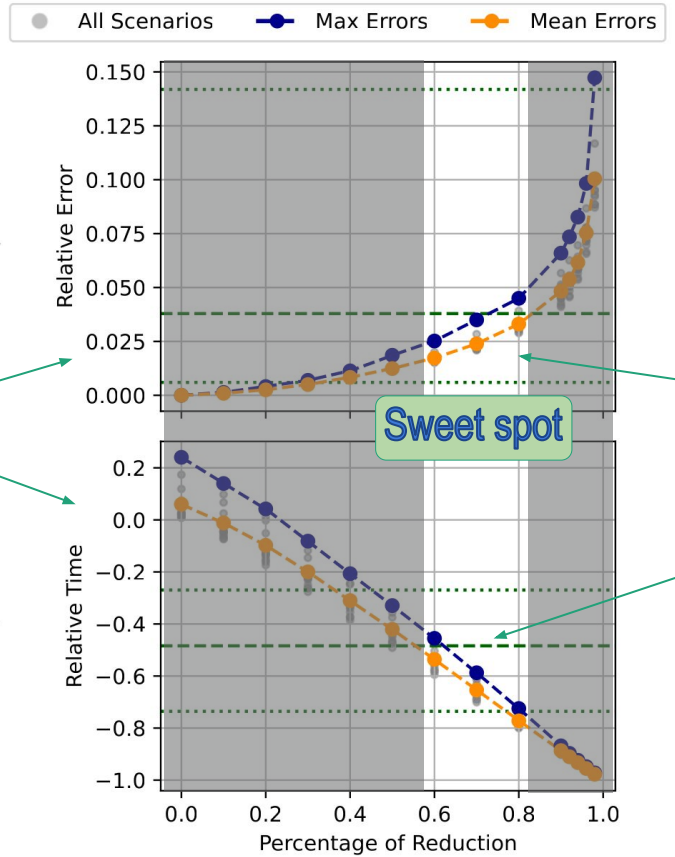
Module-level performance for comparison

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SFA performance results

$$Relative\ Error = \frac{\sum \left| MPP_{new\ method} - MPP_{reference\ method} \right|}{\sum MPP_{reference\ method}}$$

$$Relative\ Time = \frac{time_{new\ method} - time_{reference\ method}}{time_{reference\ method}}$$



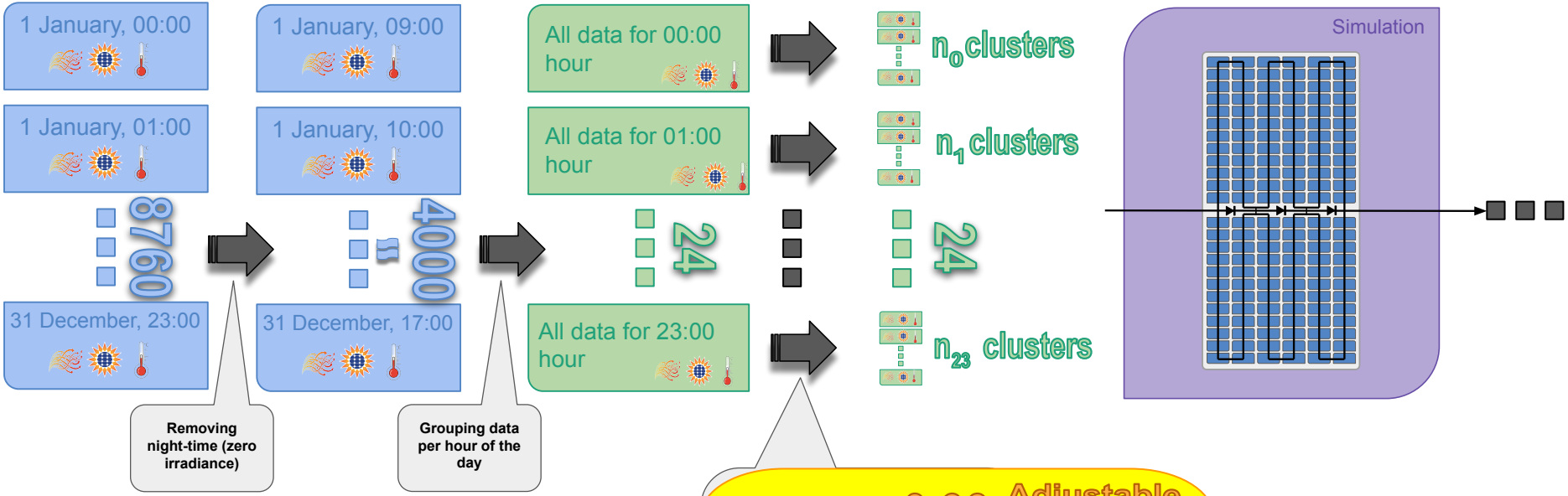
More stable results!

Less errors than module-level simulation

More reduction in computational time than module-level simulation

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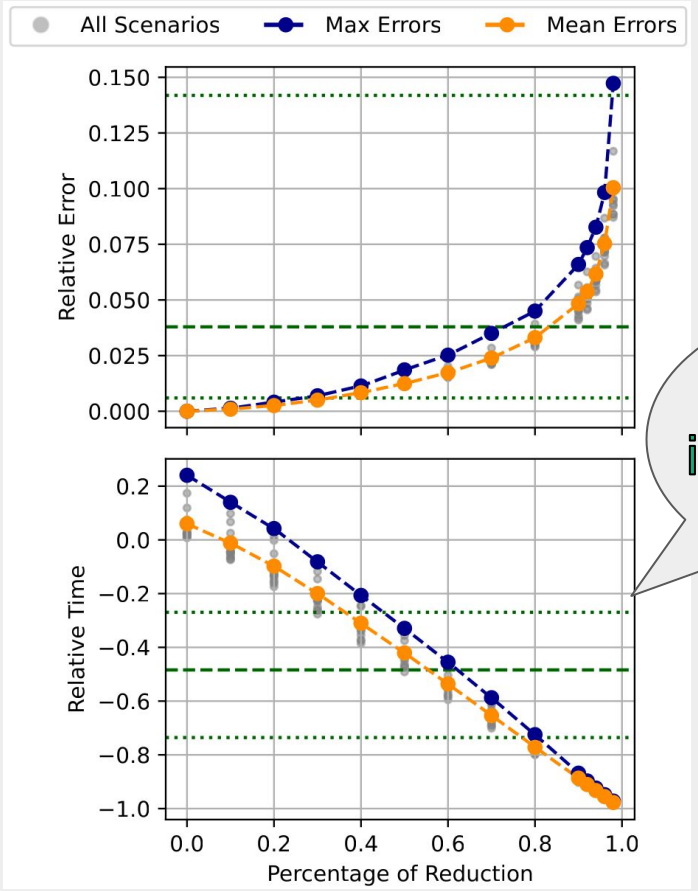
Hierarchical Hourly Aggregation (HHA)



more complex and less interpretable way of selecting the number of clusters compared with SFA

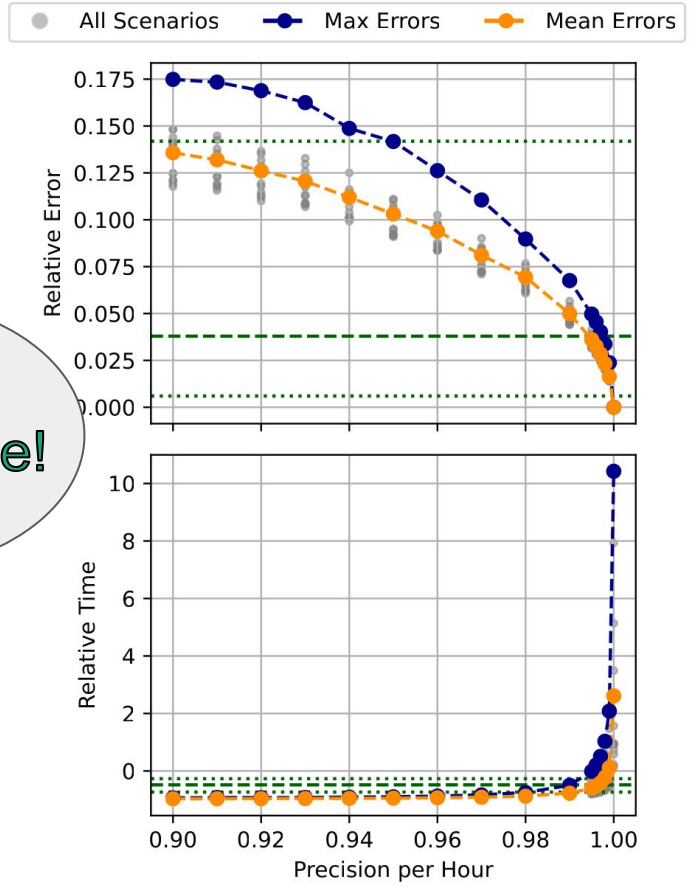
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SFA performance



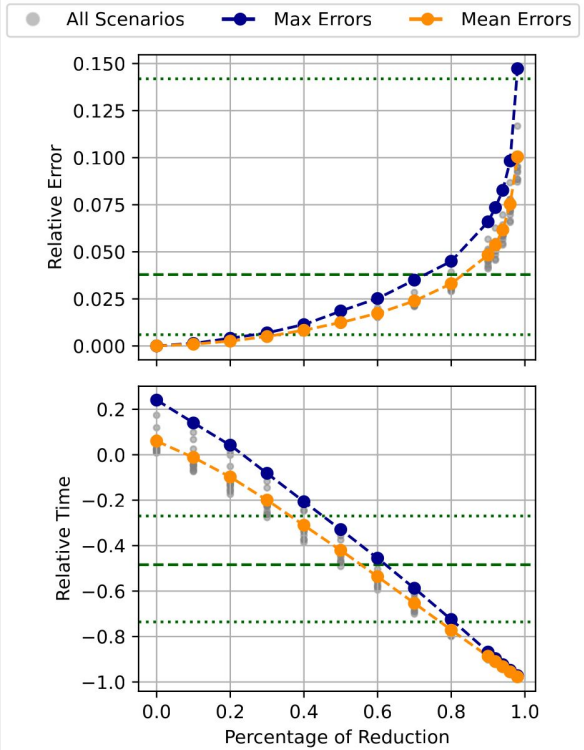
More interpretable!

HHA performance



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How do we compare both methods?



mean

$$Relative\ Error = \frac{\sum \left| MPP_{new\ method} - MPP_{reference\ method} \right|}{\sum MPP_{reference\ method}}$$

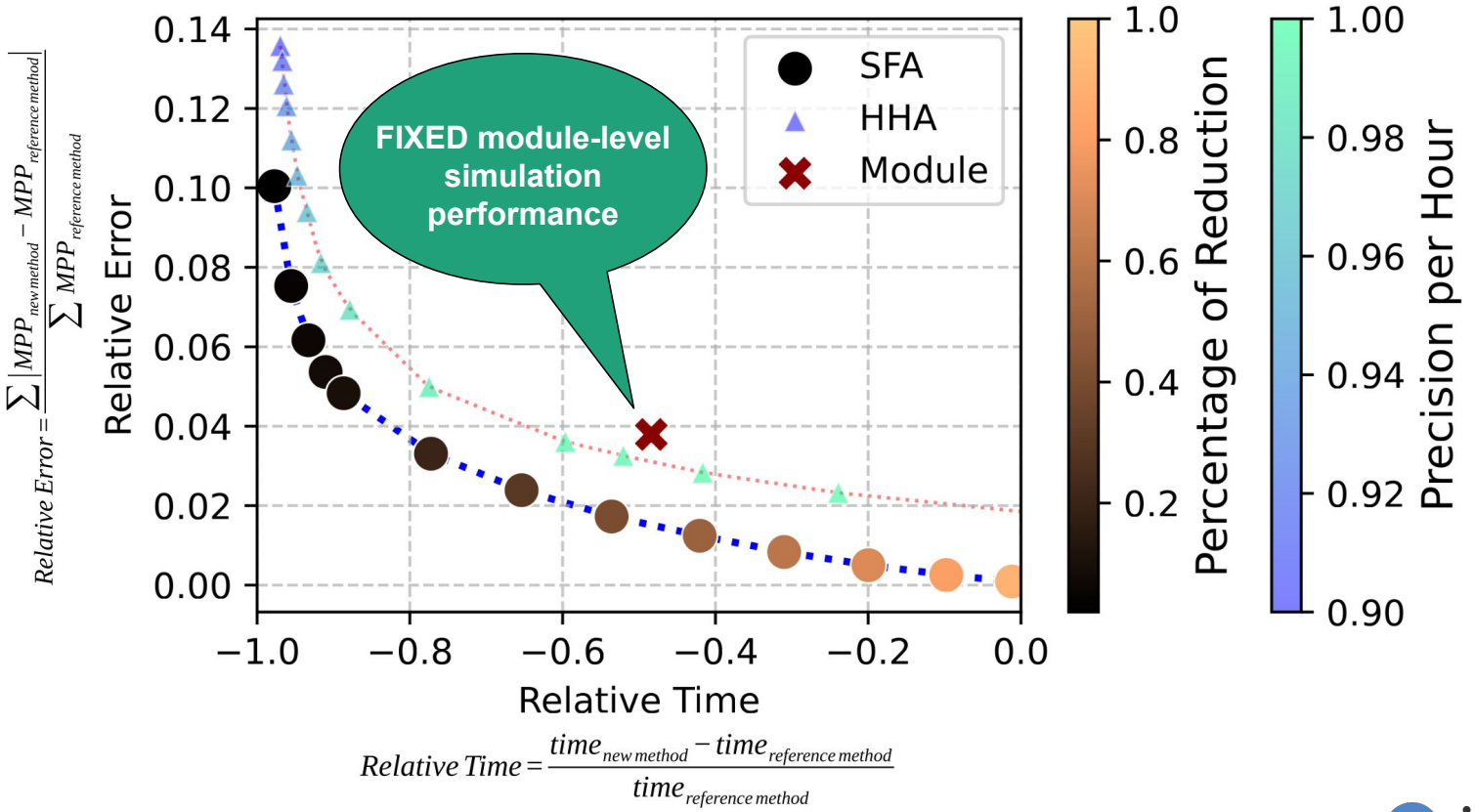
VS

mean

$$Relative\ Time = \frac{time_{new\ method} - time_{reference\ method}}{time_{reference\ method}}$$

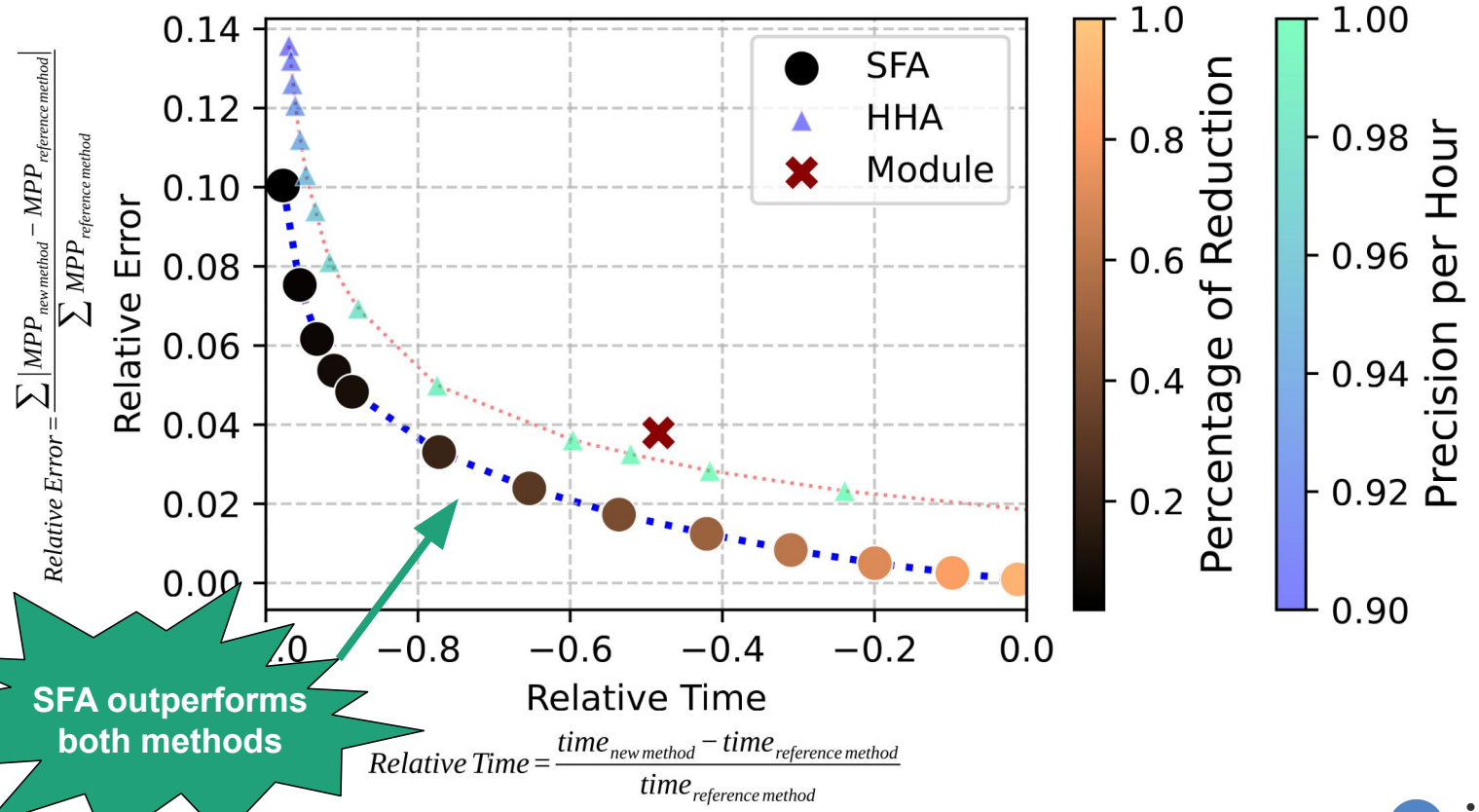
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Methods comparison (Pareto Frontier)



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Methods comparison (Pareto Frontier)



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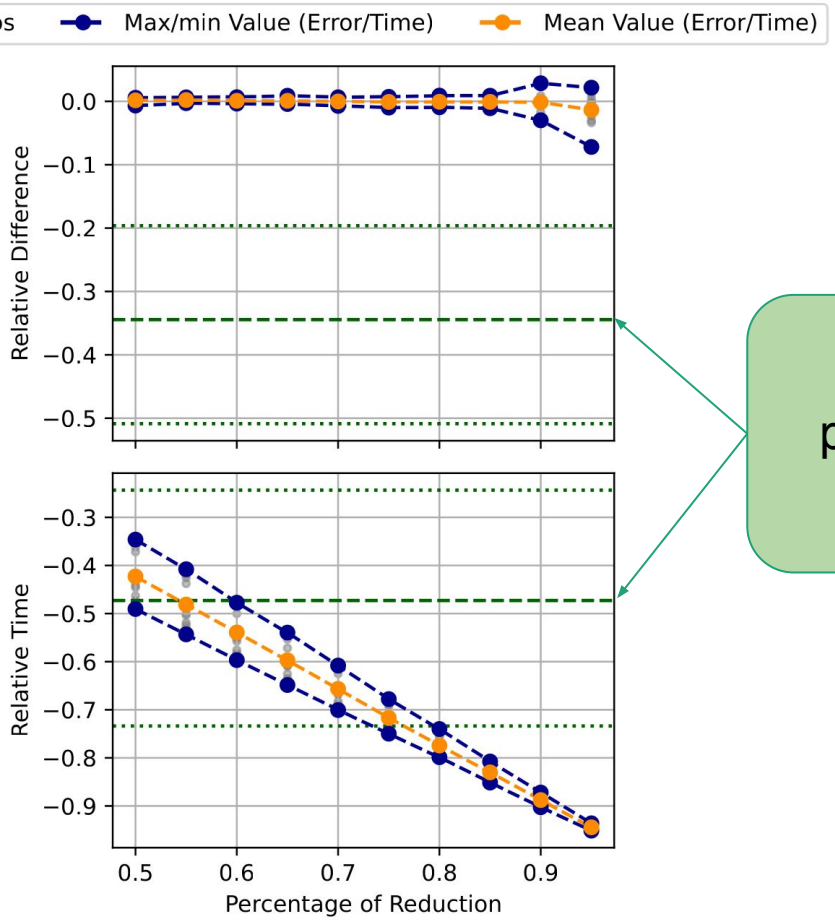
Performance in terms of total annual power loss caused by partial shading (SFA)

$$MPP_{loss} = MPP_{no\ shading} - MPP_{shading}$$

$$Relative\ Difference = \frac{\sum \left(MPP_{loss\ new\ method} - MPP_{loss\ reference\ method} \right)}{\sum MPP_{loss\ reference\ method}}$$

$$= \frac{\sum MPP_{loss\ new\ method}}{\sum MPP_{loss\ reference\ method}} - 1$$

$$Relative\ Time = \frac{time_{new\ method} - time_{reference\ method}}{time_{reference\ method}}$$



Module-level performance for comparison

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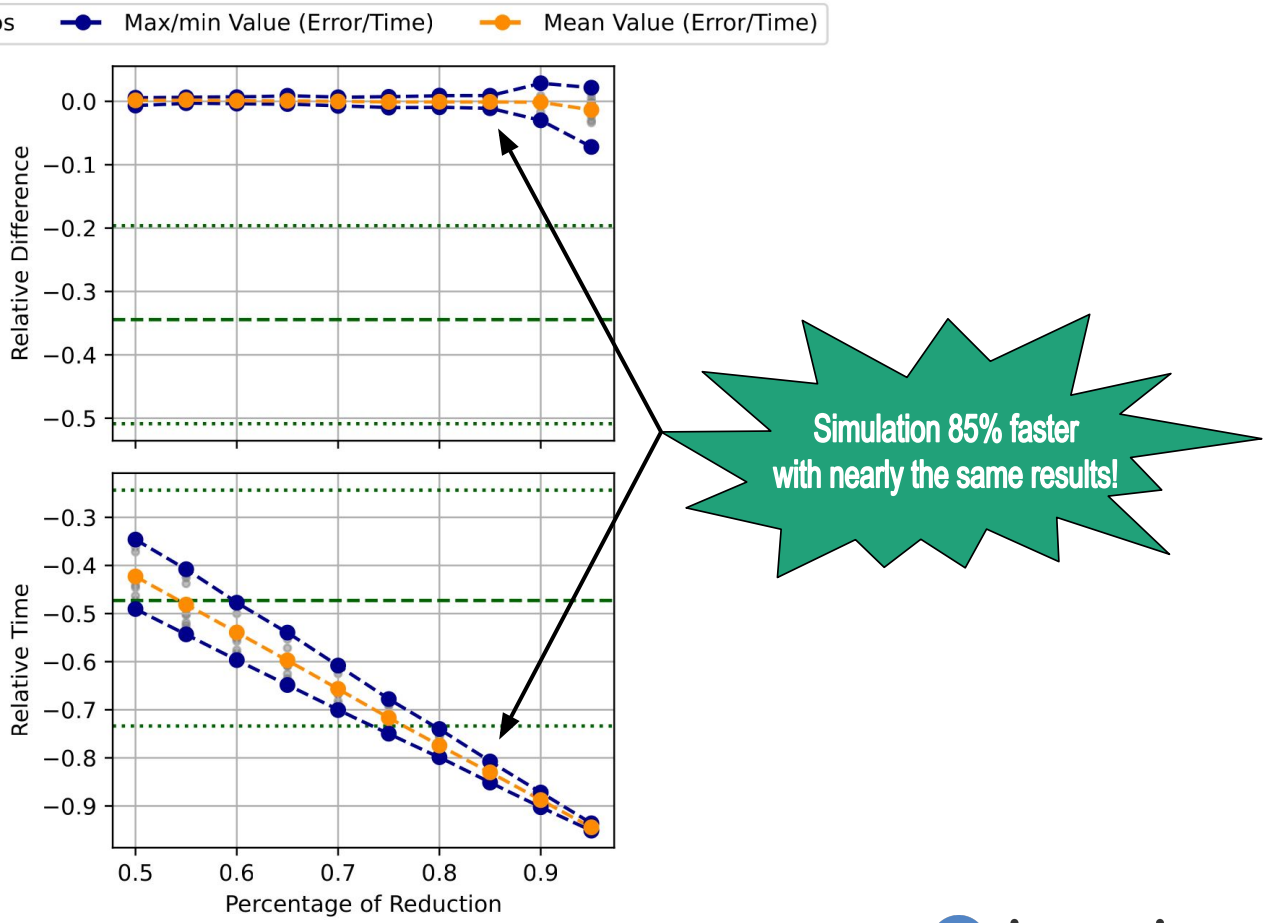
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$$= \frac{\sum MPP_{loss\ new\ method}}{\sum MPP_{loss\ reference\ method}} - 1$$

$$Relative\ Time = \frac{time_{new\ method} - time_{reference\ method}}{time_{reference\ method}}$$



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Summary

- Aggregation methods for initial data segmentation
- Better alternative in terms of accuracy/speed trade-off than module-level simulation without aggregation
- Very tunable models depending on the use case

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END

PV shading models with pvlib

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