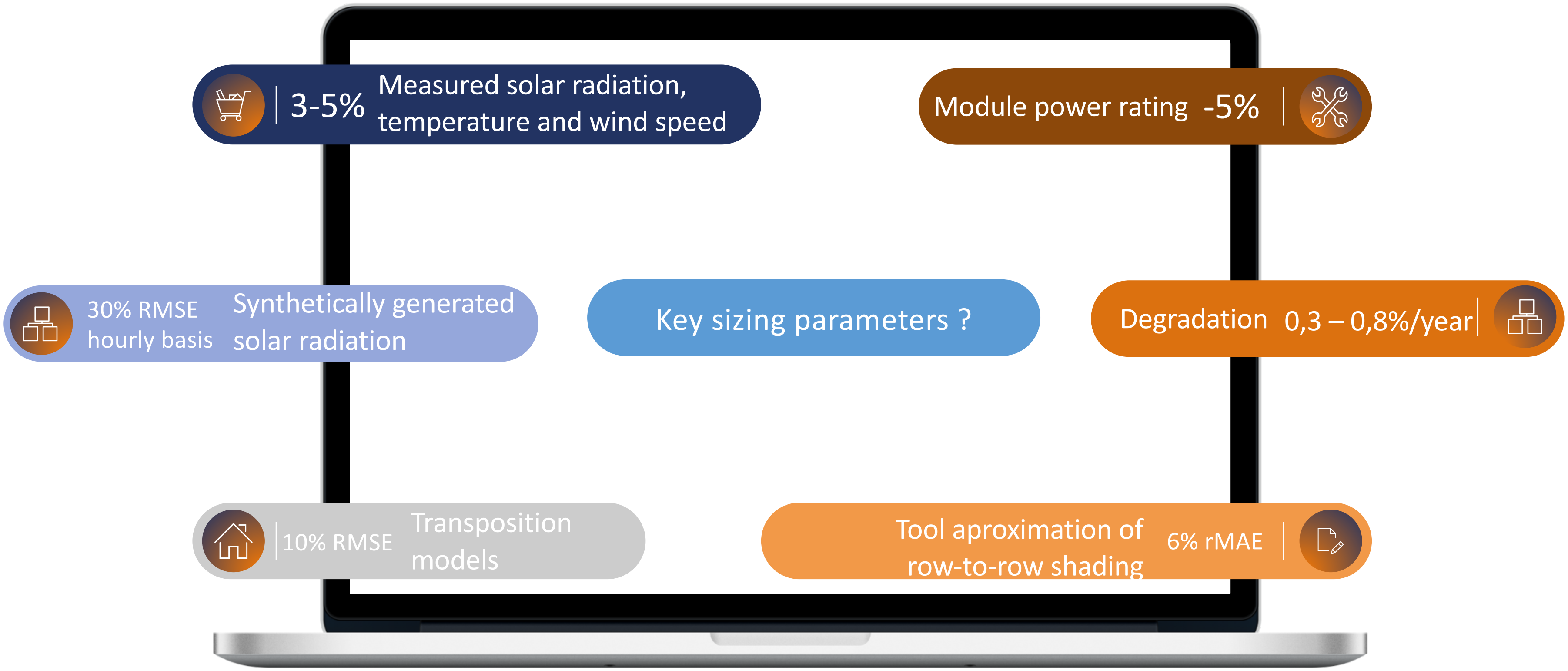
Katherine ALVINO
PhD Candidate
CES | Centre Efficacité Energétique des Systèmes of
Mines Paris

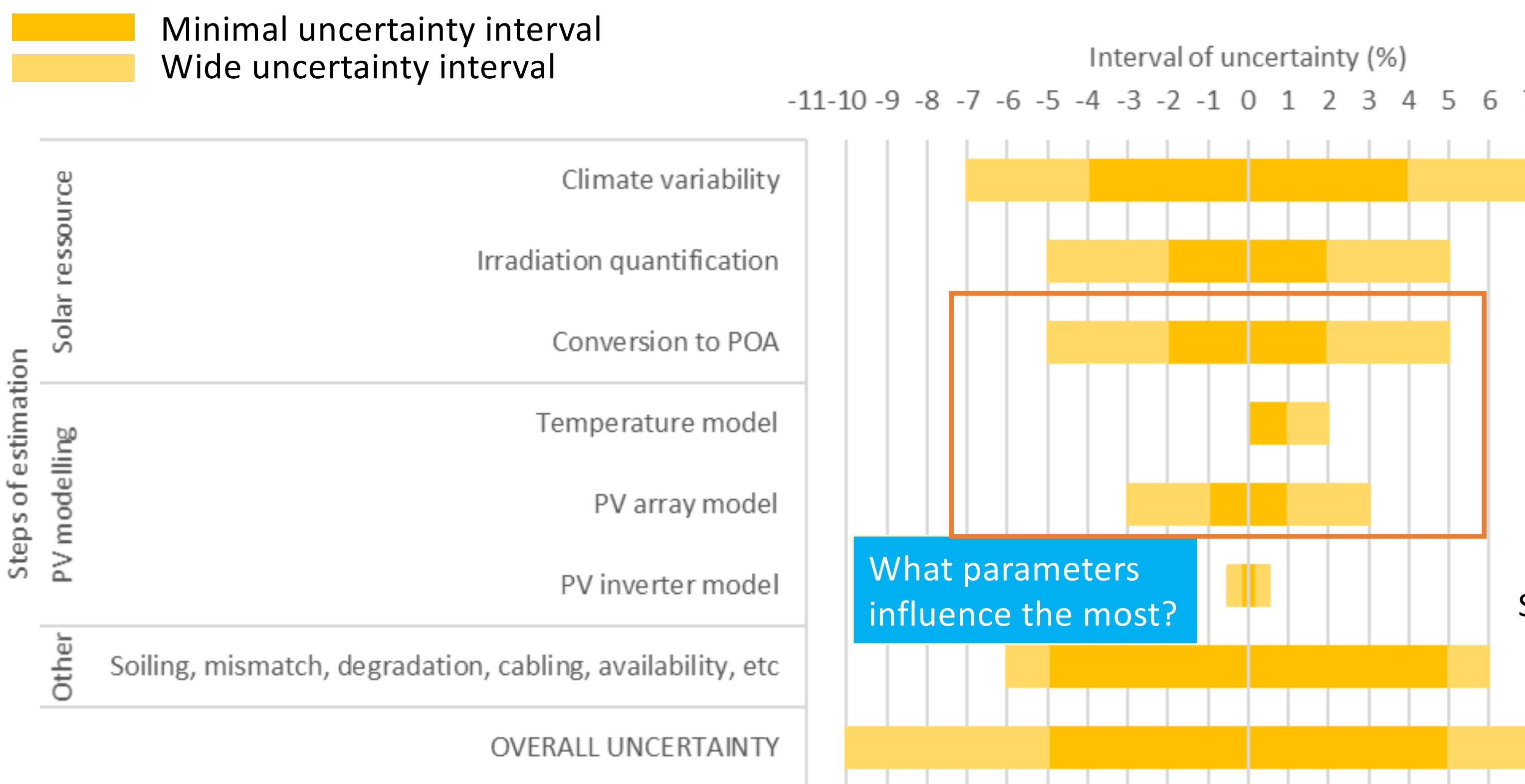
Uncertainties of module tilt and orientation, distance between rows and albedo on photovoltaic performance modeling

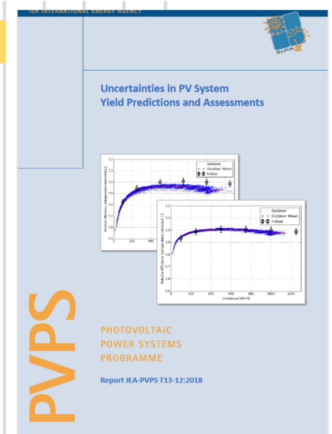
2023 European PVPMC Workshop
Wednesday, November 8, 2023

UNCERTAINTIES IN THE LITERATURE



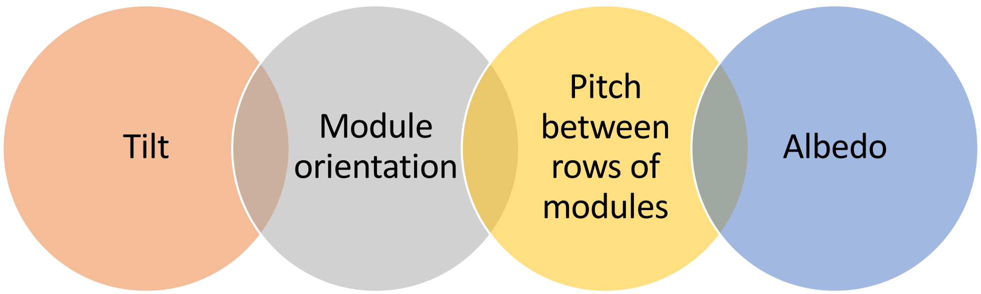
UNCERTAINTIES PER PV PERFORMANCE STEP

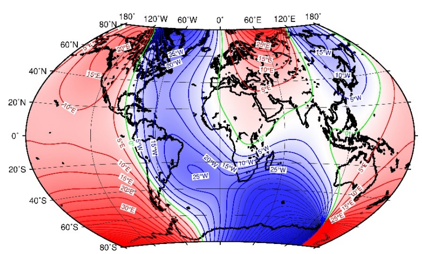




Source: IEA Task 13 report

OBJECTIVES





Map of declination (degrees East or West of true north) at 2020.0
Source: British Geological Survey

To rate parameter uncertainties per order of influence, taking into account a yearly basis

To compare the propagated uncertainty while using three values of **temperature coefficient**

To detect **interaction effects** between parameters

METHODOLOGY

Using an in-house based tool : PV Prod

Optimization

Objective: higher DC energy output per square meter of module

Modules: Splitmax 340 (Trina Solar)

Inverter: CL 36.0 (Fronius)

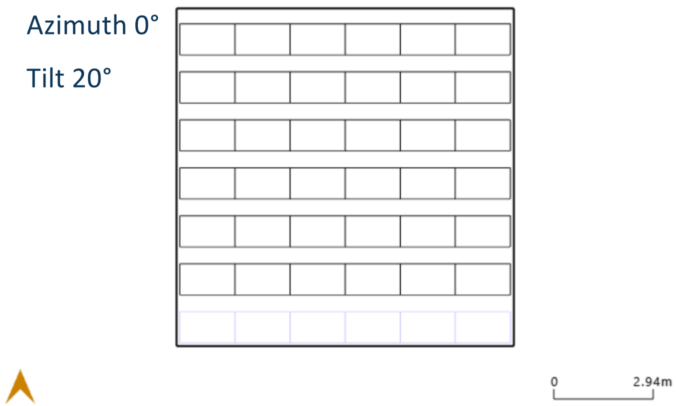
Global sensitivity analysis

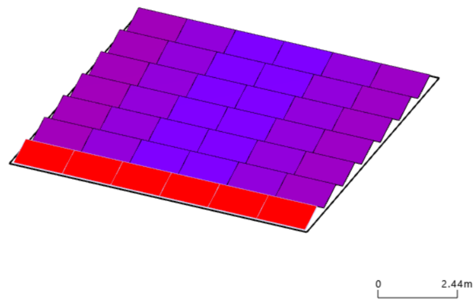
Sampling of parameters

Evaluations of the model

Estimation of sensitivity coefficients

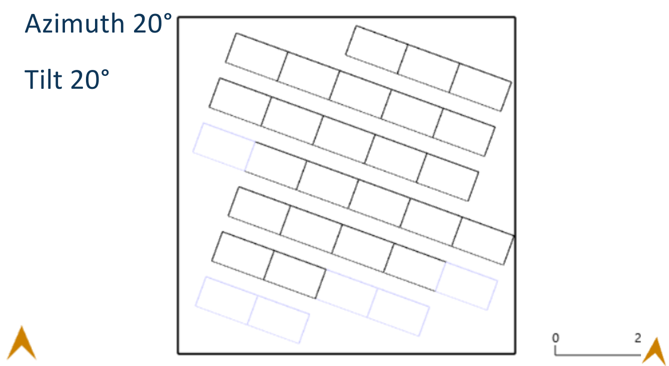
PV PROD TOOL FOR PV PERFORMANCE (MODULE IN CLIMAWIN OF BBS SLAMA)

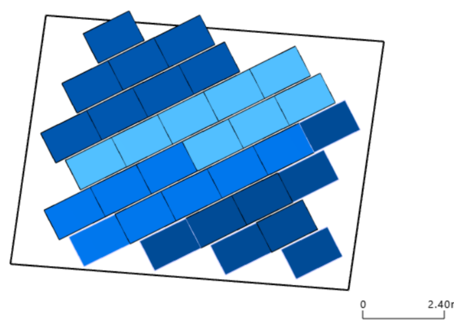




Color per yearly irradiation

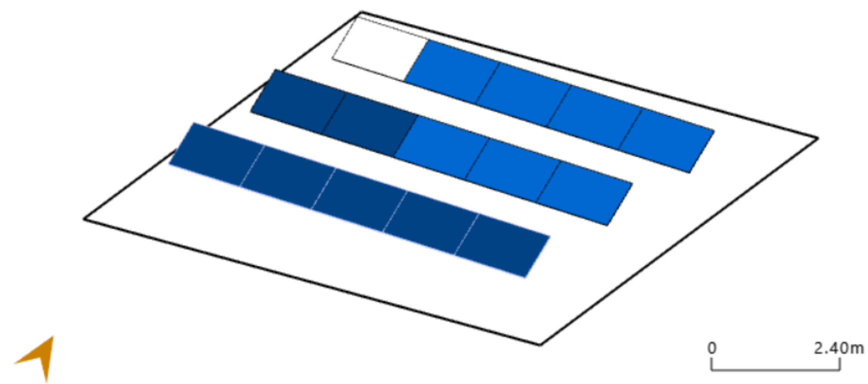
Multiple evaluations





Color per string connection

OPTIMIZATION: HIGHER ENERGY YIELD kWh/kWp



Uncertain parameter	Distribution	Boundaries	Optimized configuration Marseille
Orientation of the modules	Uniform	-90° to 90°	3.80°
Tilt of the modules	Uniform	0° to 90°	33.31°
Pitch between rows	Uniform	0 to 2 m	2.67 m

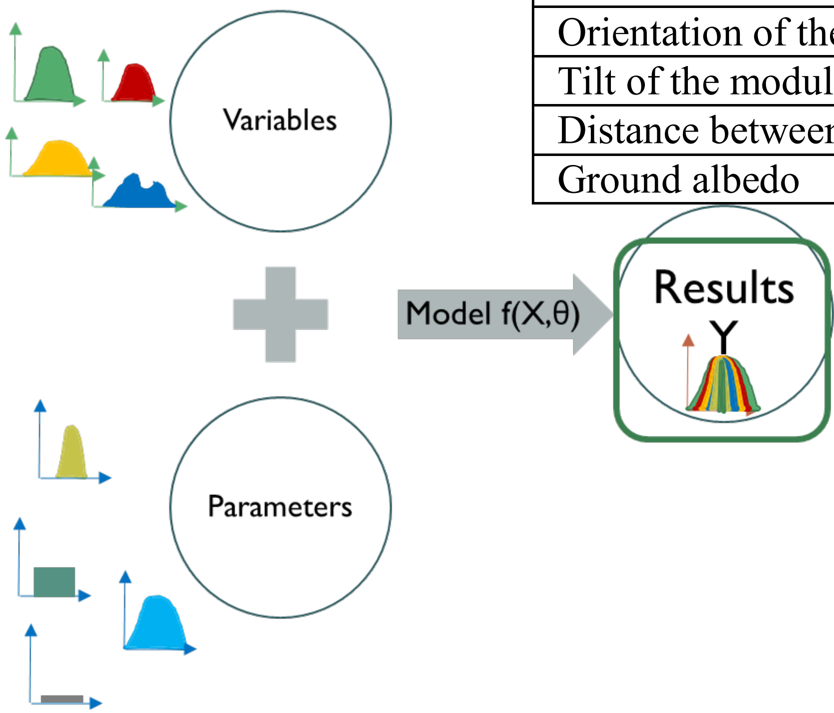
Annual energy yield of modules = 1607.2 kWh/kWp

SOBOL-HOEFFDING VARIANCE BASED GSA

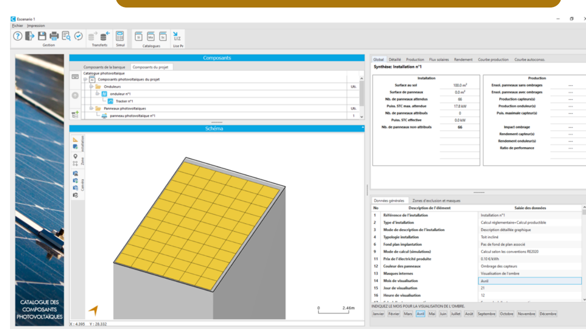
- Ilya M. Sobol’ was inspired from Cukier’s (1970) and Hoeffding’s **variance decomposition theorems**
- Sobol’ **first-order indices** are the fractions (0 to 1) of the variance explained by each corresponding parameter only
- **Second-order and high-order indices** represent the fraction of the variance explained by the parameter interactions
- All **parameters** are assumed **independent** from each other

GLOBAL SENSITIVITY ANALYSIS: PROBLEM SET-UP

Uncertain parameter	Distribution	Mean value	Standard deviation
Orientation of the modules	Normal	3.80°	10°
Tilt of the modules	Normal	33.31°	4°
Distance between rows	Normal	1.84 m	0.1 m
Ground albedo	Normal	21%	4%

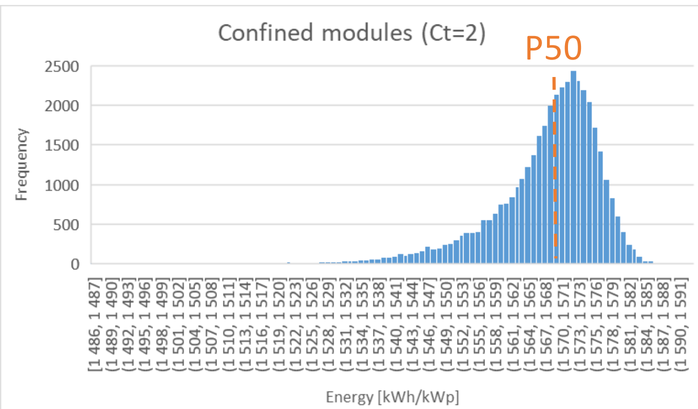


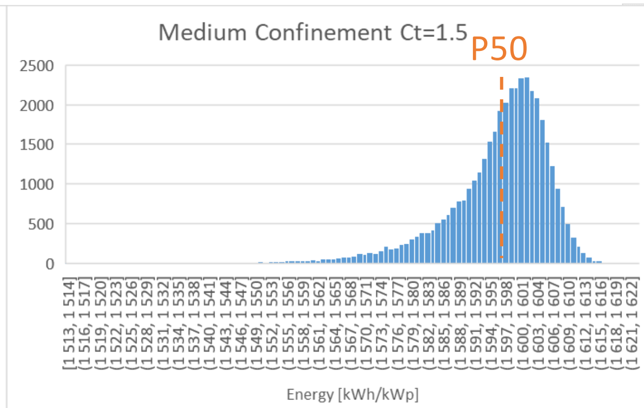
Sampling: Sobol quasi random sequences

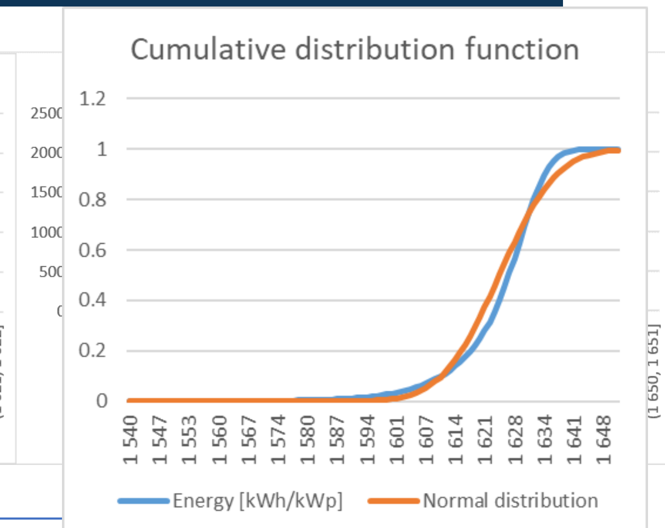


40960 SIMULATIONS

RESULTING DISTRIBUTIONS FOR THREE CASES

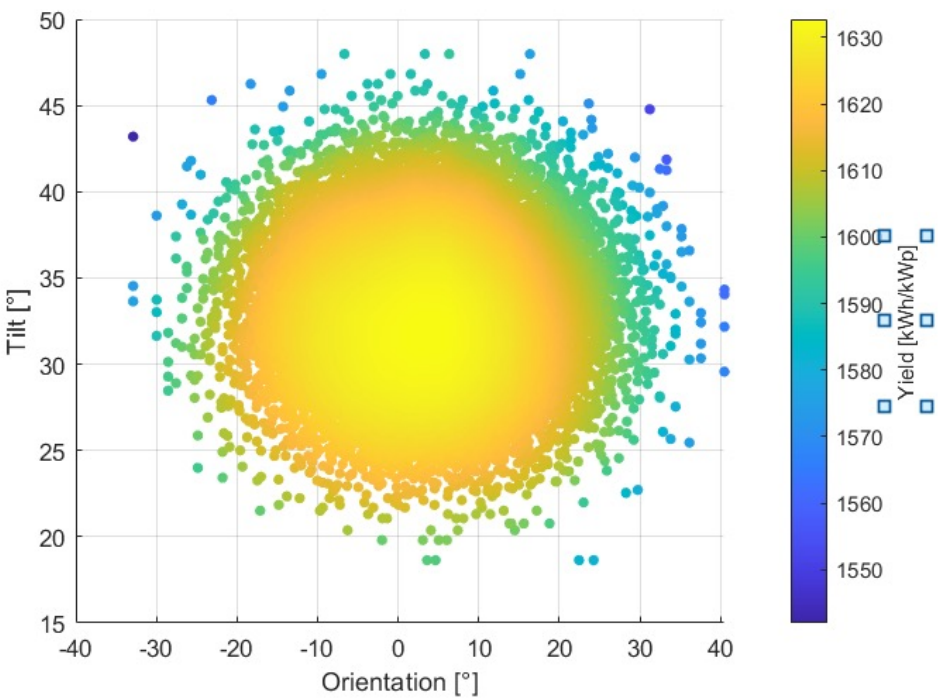


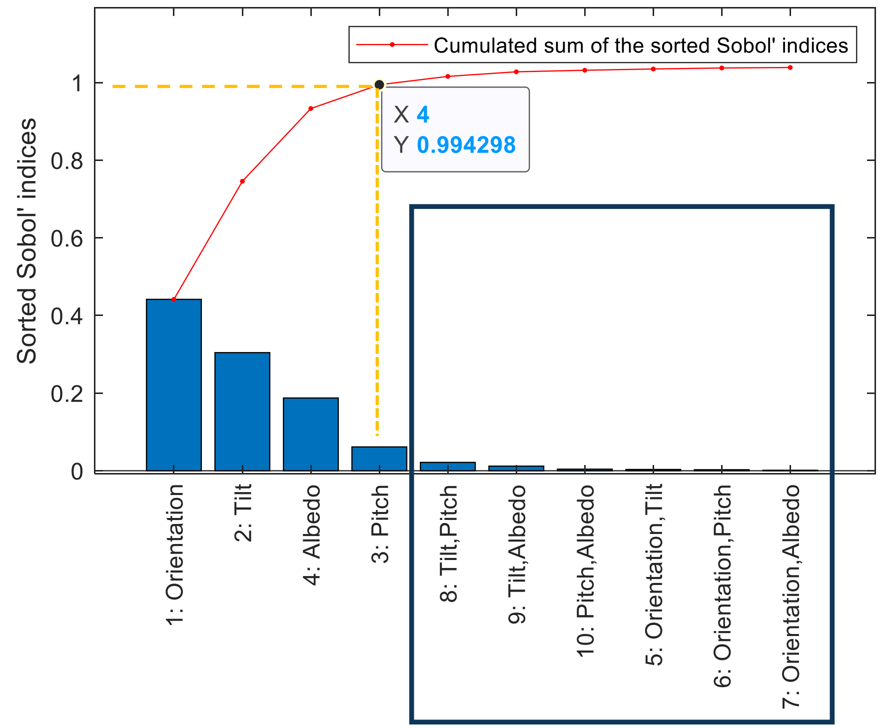




	Temperature coefficient = 2	Temperature coefficient = 1.5	Temperature coefficient = 1
P50 (kWh/kWp)	1569.33	1596.71	1624.08
SD	9.73	10.00	10.27
SD/Mean (%)	0.62%	0.63%	0.63%

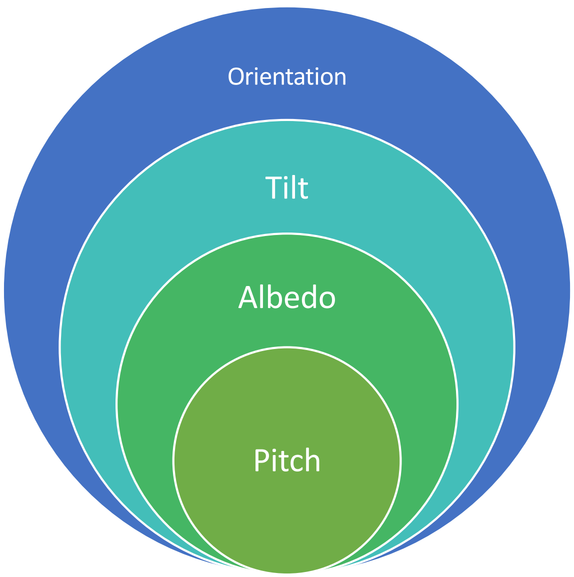
SENSITIVITY INDICES: TEMPERATURE COEFFICIENT = 1





INTERACTION EFFECTS

CONCLUSIONS



The standard deviations in three cases correspond to 0.63%

Sensitivity indices: Orientation > Tilt > Albedo > Pitch

$$S_{orientation} + S_{tilt} + S_{pitch} + S_{albedo} = 0.99$$

Non-significant interaction effects

Normal uncertainties → not-normal resulting distribution

PERSPECTIVES

Uncertainties during different moments of the year (monthly)

Uncertainties under different configurations

Uncertainties under different models

Uncertainties under different locations, different datasets

Marseille, France

Roskilde, Denmark

- Available database

Acknowledgements

- Julien Liochon (BBS Slama)
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- Boutros Ghannam (CES Mines)

THANK YOU

katherine.alvino@minesparis.psl.eu

HOW TO REDUCE UNCERTAINTY IN PROJECT PLANNING?

CHALLENGES: How to increase the photovoltaic energy generation within a market that requires predictable energy production? Is it possible to cover an important share of the "energy mix"?

SCIENTIFIC QUESTIONS

→ What is the modelling uncertainty of a PV Performance method?

→ What are the sources of uncertainty? What is their influence? Their interactions?

→ How does uncertainty propagate to the modelling output?

→ How does uncertainty translate for different outputs?

→ Do PV performance tools have the same uncertainty for different tilts, orientations and scenarios?

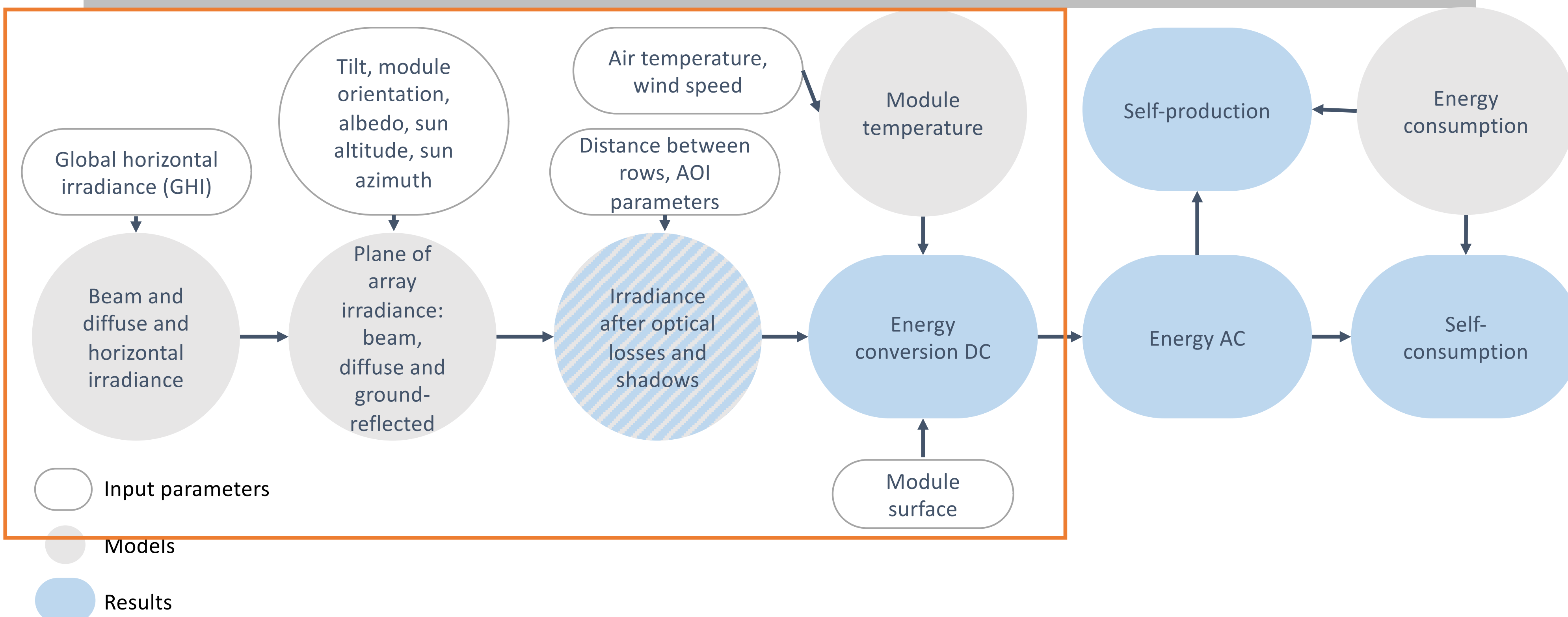
CHALLENGES

→ To compare heterogeneous results

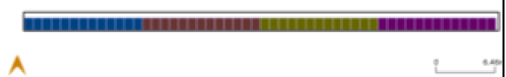
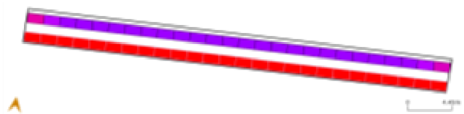
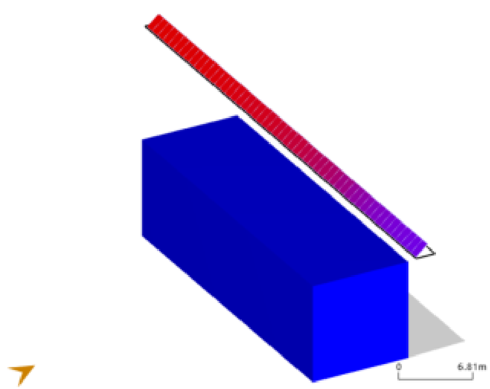
→ To separate model uncertainty from the uncertainty of measurement

→ High number of uncertainty sources and of interactions between them

STEPS/MODELS OF METHOD



RESULTS (PV PROD COMPARED TO PVSYST)

Scenario	Yearly MBD (%)	Monthly MBD (%)	Hourly RMSD
One row without shadows 	0.1%	Overestimation during the winter (up to 1.1% MBD) and underestimation during the summer (down to -1.3% MBD	8.8%
Two rows with 1 m of distance between rows 	-1.3%	-7.6% during winter to 1.8% during summer	9.5%
One row with building block 	4.3%	1.4% in November to 6.8% in April	24.8%