



Experimental study and numerical simulations of the airflow around a photovoltaic panel on a building roof

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Outline

- Context : PROOF project
- Goals
- Materials and Methods
- Results
- Discussions and Outlook

PROOF project



Biosolar roofs

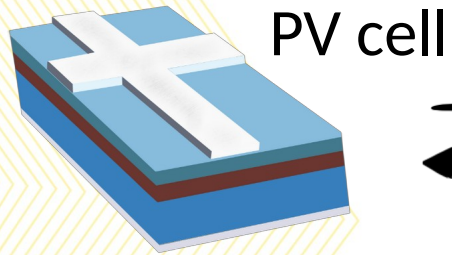
Microclimate cooling effect of GR to improve PV energy production efficiency ?

Ecological benefits of the combined system ?

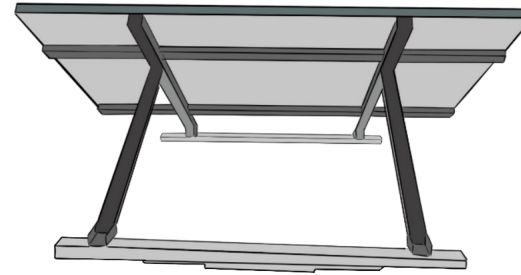
- muticriteria (microclimate, energy, hydrological, biodiversity & life cycle assessment)
- multiscale (system → urban)



General framework

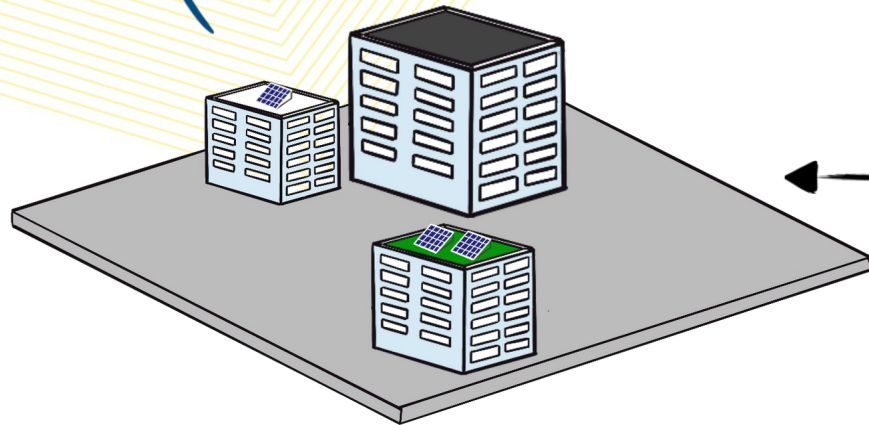


PV cell

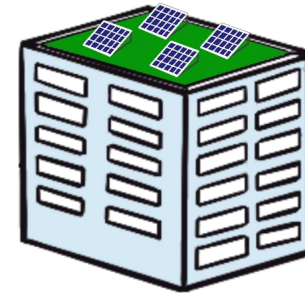


PV panel

Optimal design



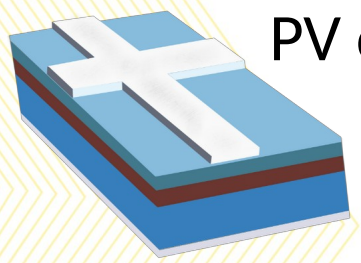
Urban environment



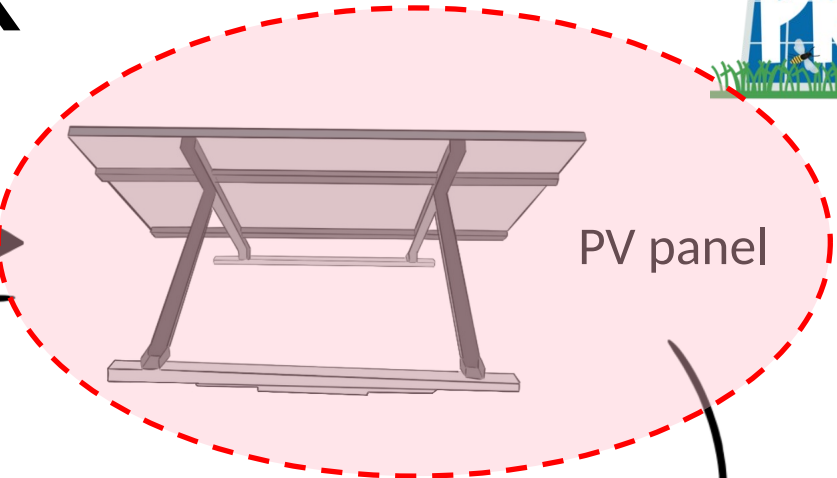
Building



General framework

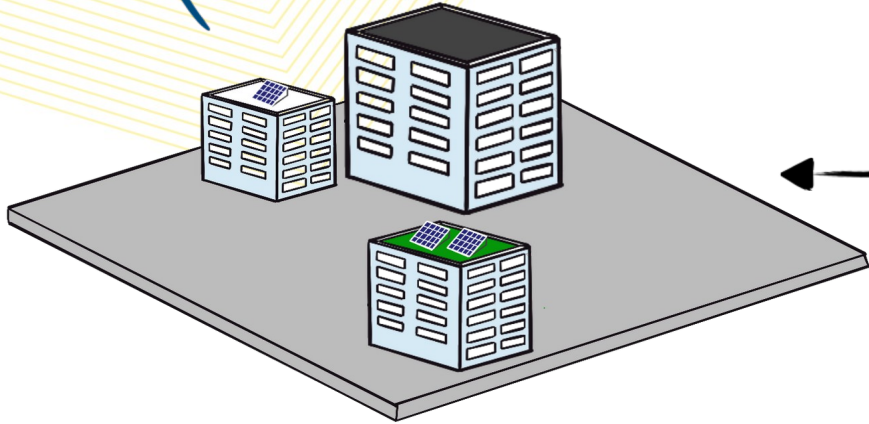


PV cell

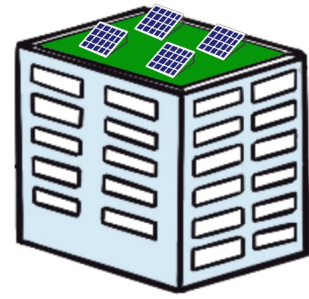


PV panel

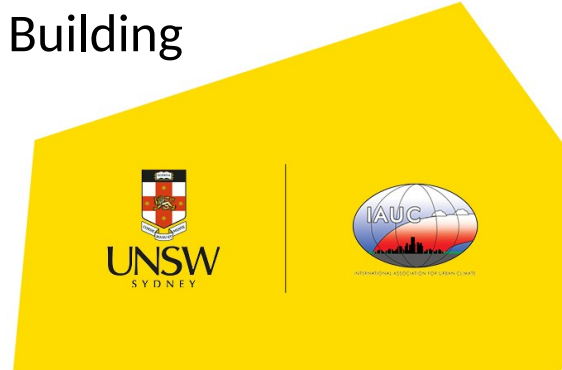
Optimal design



Urban environment



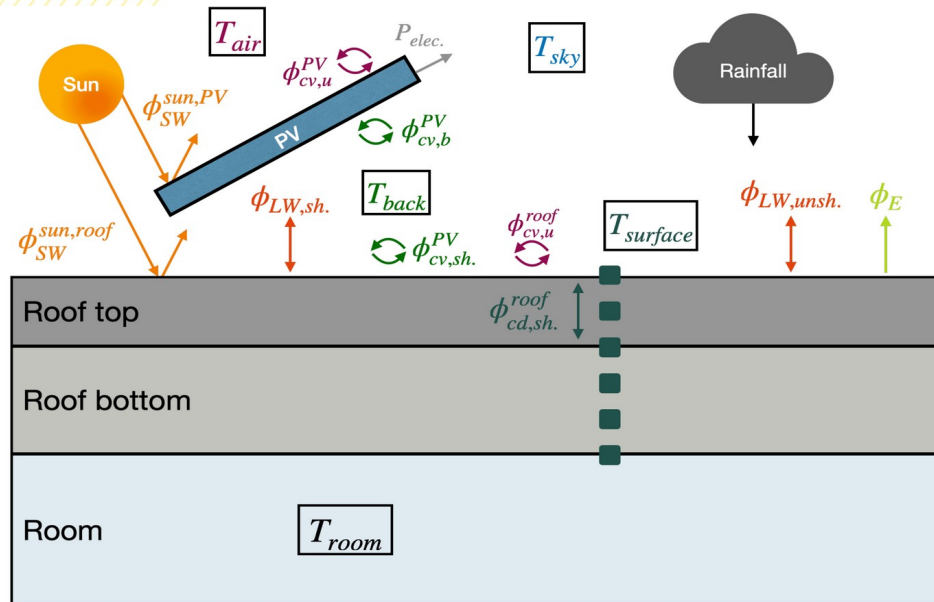
Building



Thermal transfers modelling



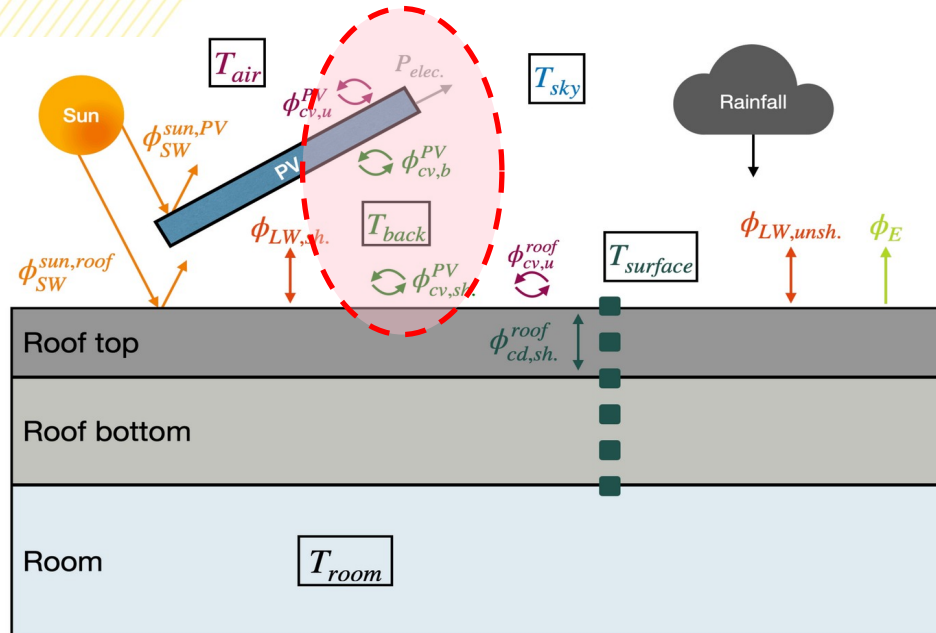
- Understanding and modelling microclimatic processes around the panel
- Modeling PV energy efficiency as a function of roofing surface types



Thermal transfers modelling



- Convective flux(es) ?

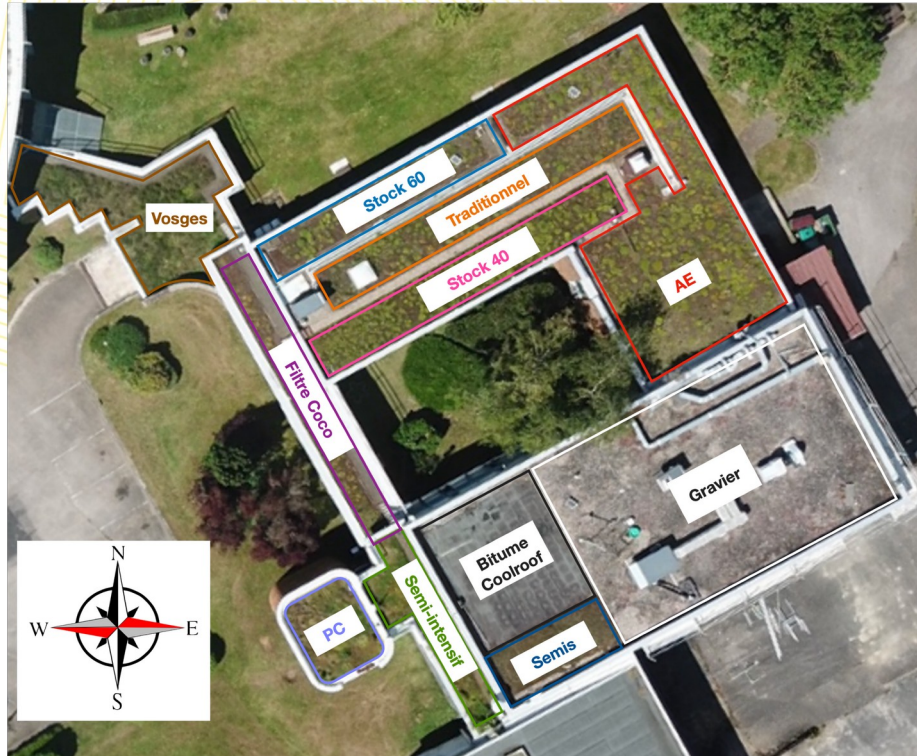


Goals

- Use CFD simulations to better understand the effect of the PV panel's layout and geometry on nearby flows
- Determine a parametrization for the convective flow exchanged between the PV panel and its environment
- Confront with experimental measurements
- Integration of these results in the global thermal model

Materials & Methods : experimental

Green Roof research platform at Cerema, Nancy



Materials & Methods: experimental



Green roof platform



Coolroof platform



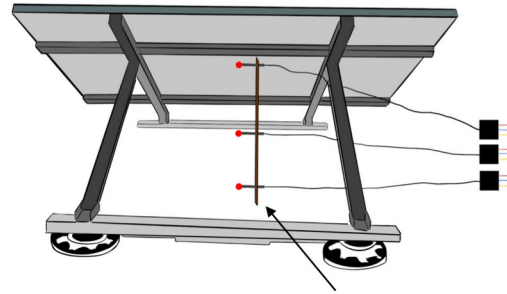
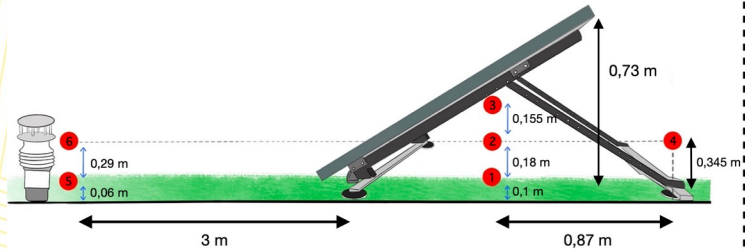
Gravel platform



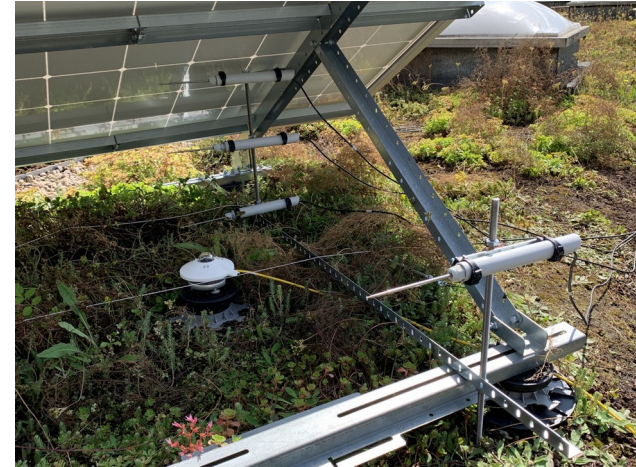
Bitumen platform

Materials & Methods : experimental

Airflow experimental campaign (2021 & 2022)

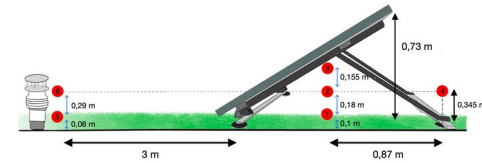
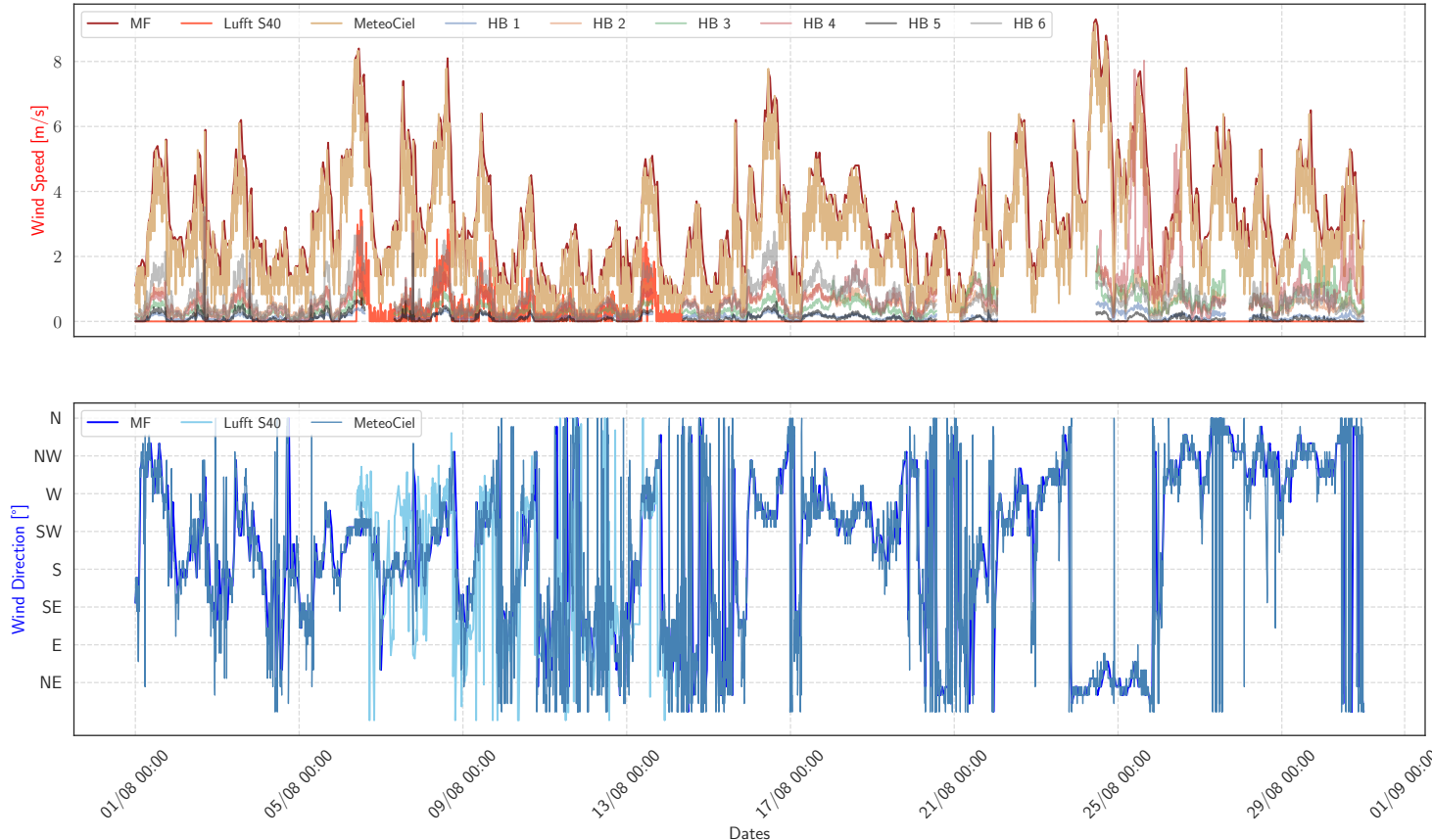


- Reference site and local meteorological stations
- Wind hot balls sensors
- SW radiative sensors
- Back surface temperature and convective fluxmeters



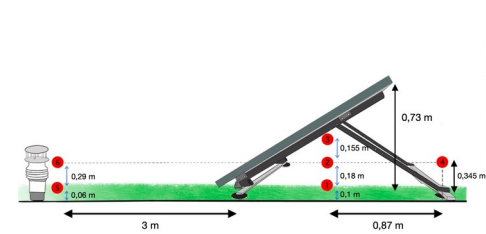
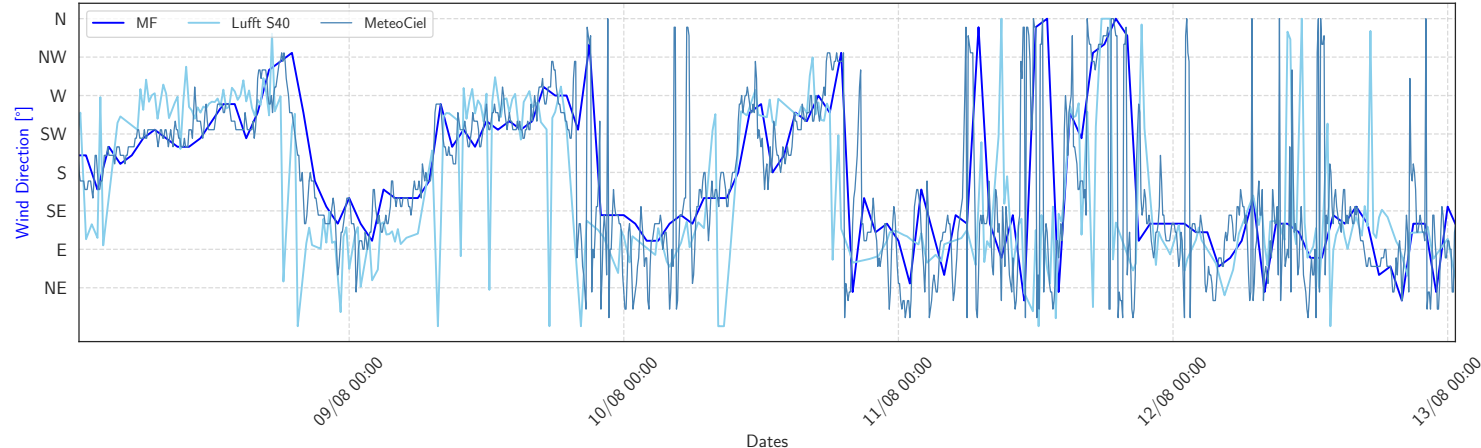
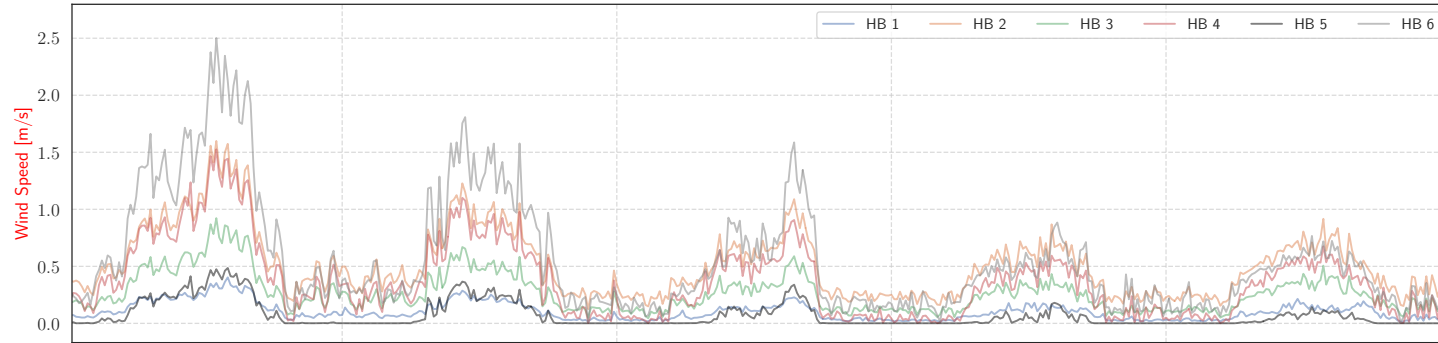
Materials & Methods : experimental

Wind measurements



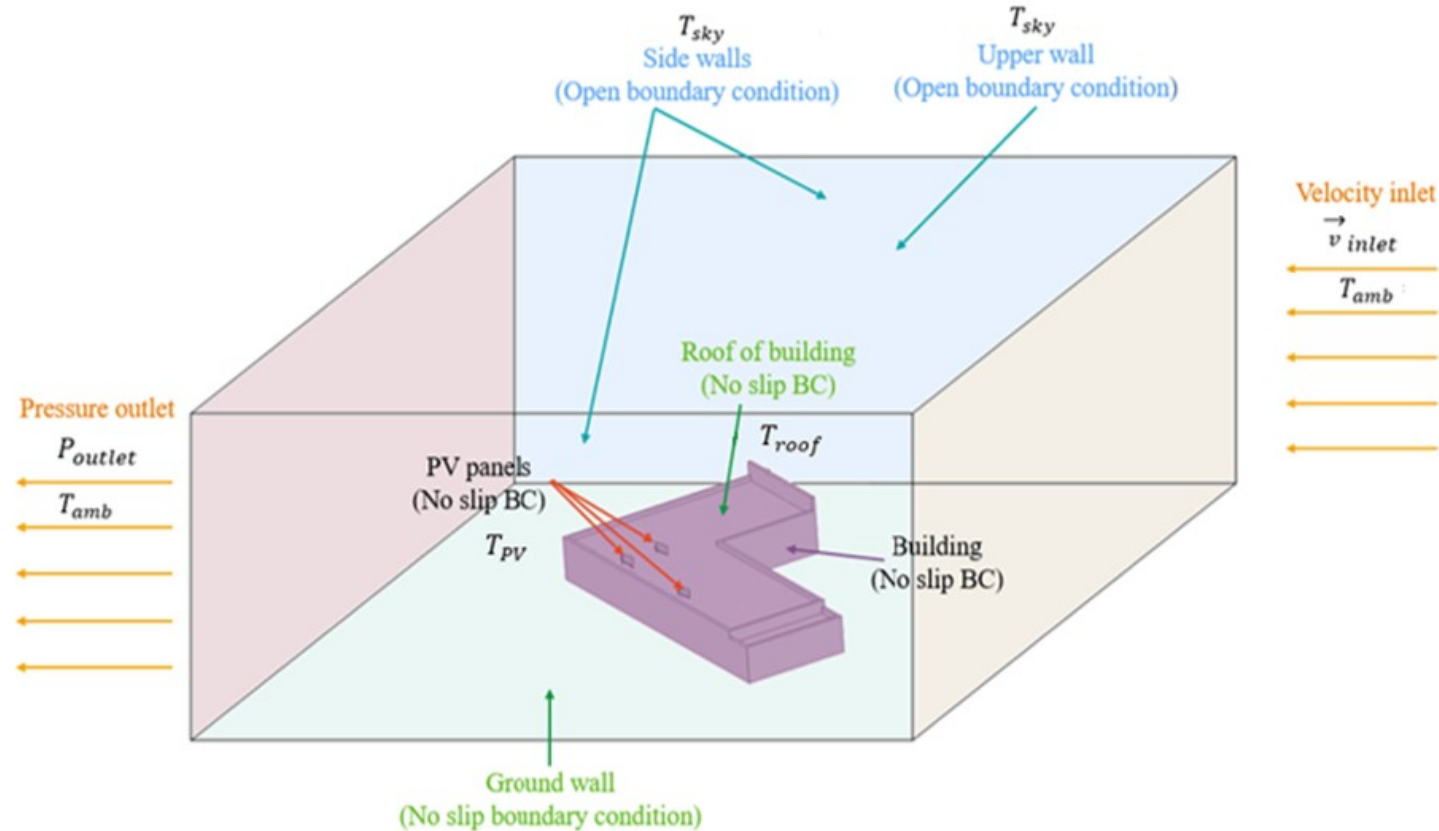
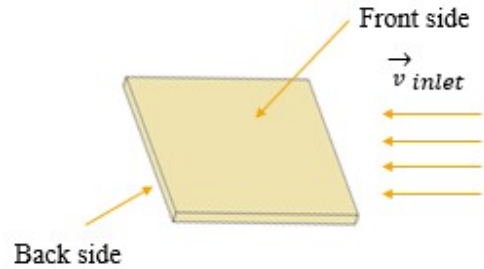
Materials & Methods : experimental

Wind measurements



Materials & Methods : CFD modelling

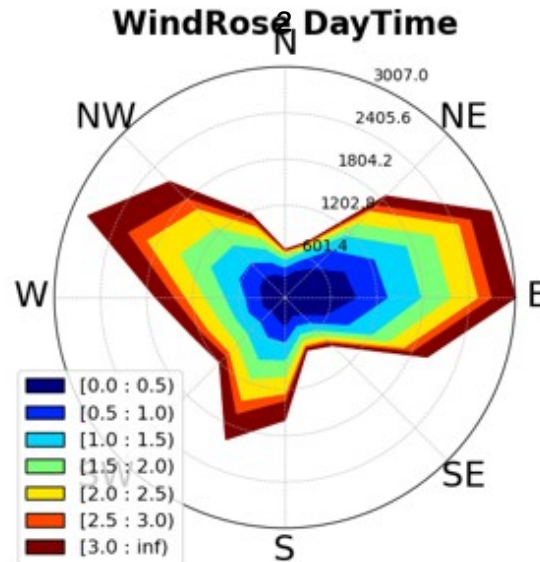
Fluent
RANS k-eps model



Materials & Methods : CFD modelling

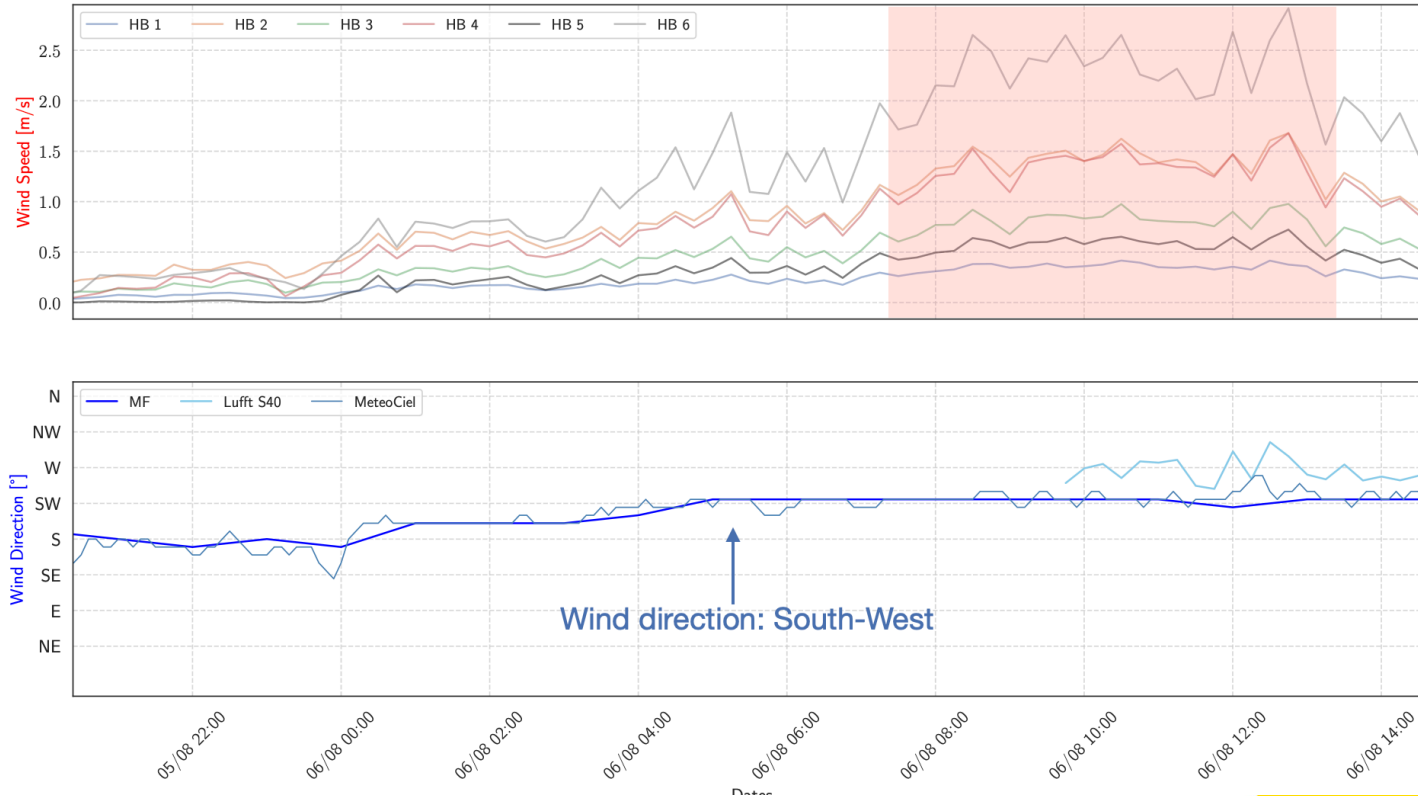
Wind boundary conditions

- Wind rose study to determine prevailing winds
- 2 (from 3 main) directions saved : S & E



Materials & Methods : CFD modelling

Time window extraction for BL & mod/exp comparison



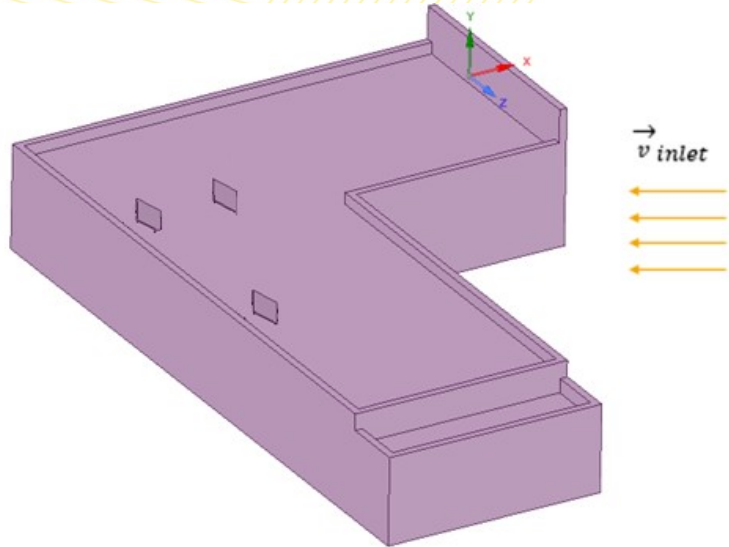
Materials & Methods : CFD modelling

Global boundary conditions (based on platform measurement data)

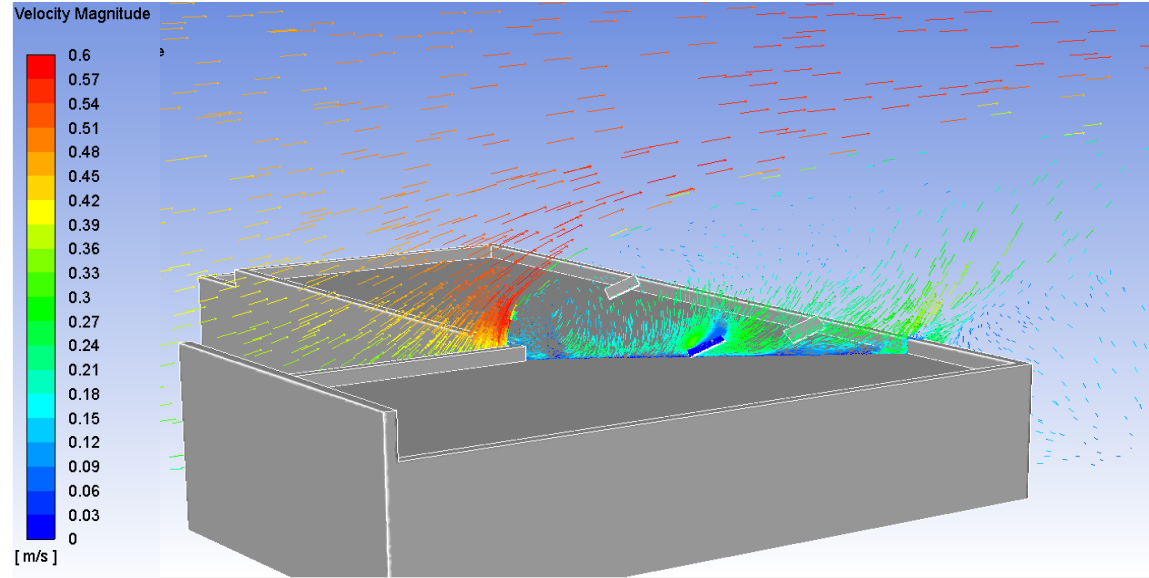
Direction	Velocity m/s	T _{amb} °C	T _{roof} °C	T _{PV} °C	Solar heat flux W/m ²	Power W
East 79° - 90°	0.42	26.05	29.3	43.37	639.8	170.2
East 79° - 90°	2.49	28.99	29.96	45.91	768.1	204.7
South 180° - 203°	0.45	25.27	31.2	45.97	682.4	181.6
South 180° - 203°	2.48	27.3	29.7	41.6	607.9	164.3

Few results

Airflow patterns (South direction)

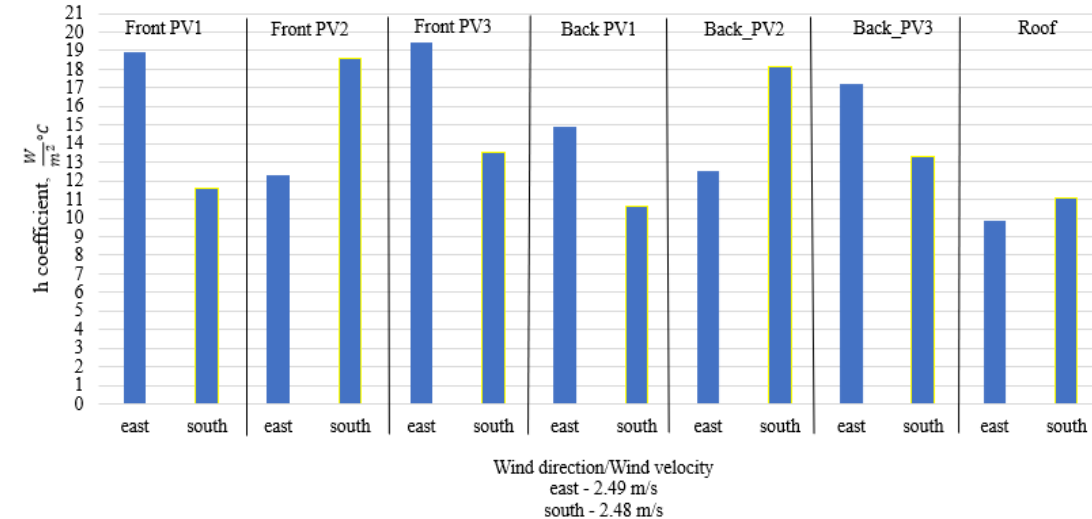
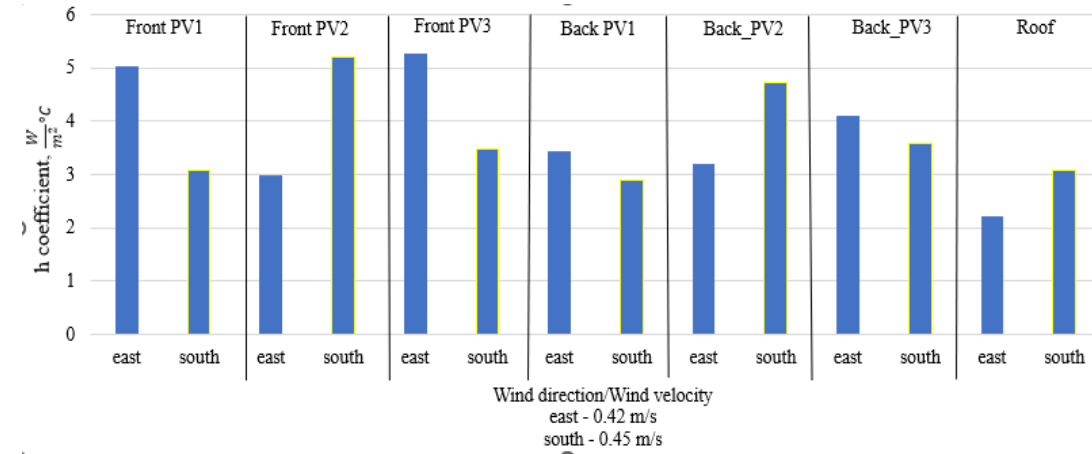
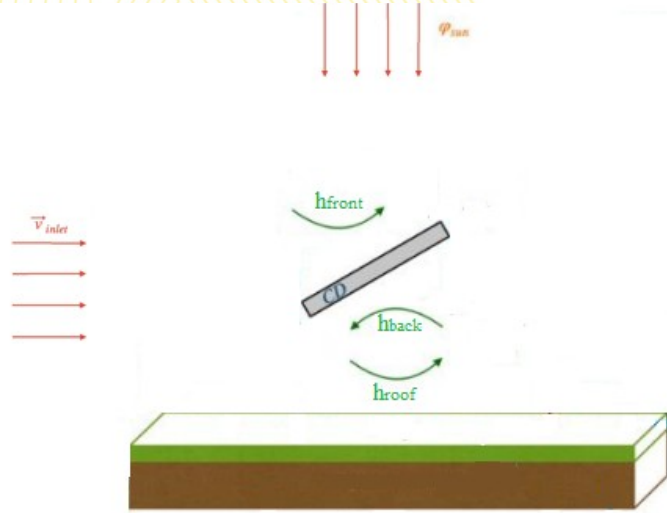


- Impact of the bulding geometry on the airflow around the PV panel !



Few results

CHTC coefficients for S and E directions



Results

The correlation that most closely - Test's , Sharples' and Sparrow's methods

East direction:

m/s	Front PV1	Front PV2	Front PV3	Back PV1	Back PV2	Back PV3
0.42	5.0	2.9	5.2	3.4	3.2	4.1
2.49	18.9	12.3	19.5	14.9	4.7	17.2

South direction:

m/s	Front PV1	Front PV2	Front PV3	Back PV1	Back PV2	Back PV3
0.42	3.1	5.2	3.5	2.9	4.7	3.6
2.49	11.6	18.6	13.6	10.6	18.1	13.3

Sum up

- A airflow dataset produced for 2 summers
- 2 prevailing wind directions studied with CFD simulation in a realistic configuration
- Several convection laws tested to compute thermal fluxes
- Comparison between experiment and simulation with significant differences, but encouraging for further work

Future work

- Assess the impact of vegetation on convective heat flux : simulation and by comparison of PV panels on vegetative and gravel platforms
- Investigate the air temperature of the sensors
- Compare sensible / latent / radiant heat fluxes : the more efficient in terms of cooling ?
- Parametric studies with geometric aspects: distance between the PV panel and the roof, inclination, relative size of the PV panel, etc.

Thanks for your attention

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Partners


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