# Dispositif climatique pour mesurer l'exposition thermique des piétons lors d'un épisode de chaleur extrême

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*Double diplôme ENSMA - Institut polytechnique de Hanoï*

*11/05/2026 – 25/09/2026*

ENERGY AND INDUSTRY OF THE FUTURE

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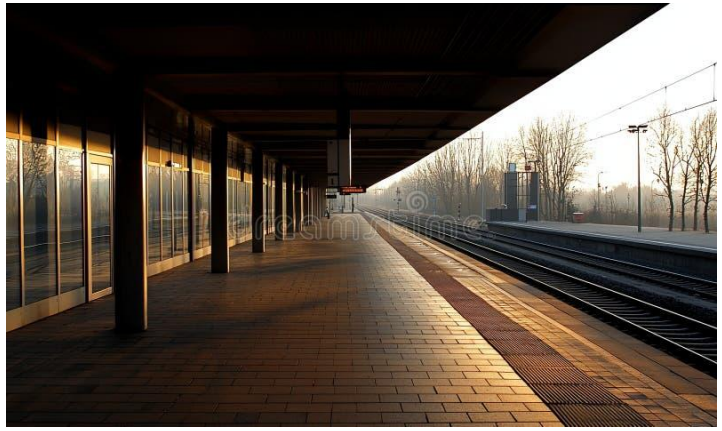
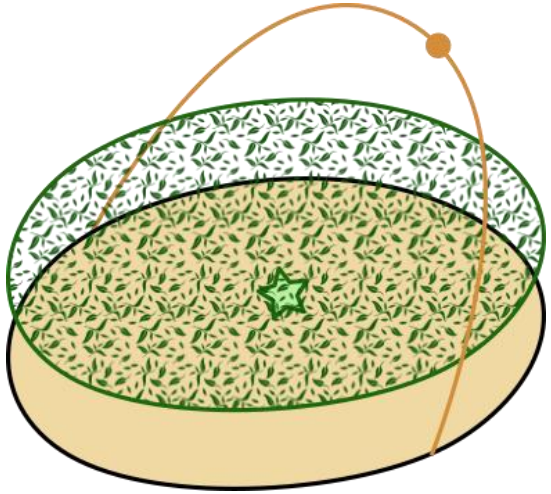
1. ***Contexte de la recherche***
2. ***Dispositif: conception et test***

## Abris bâtis pour se protéger de la chaleur

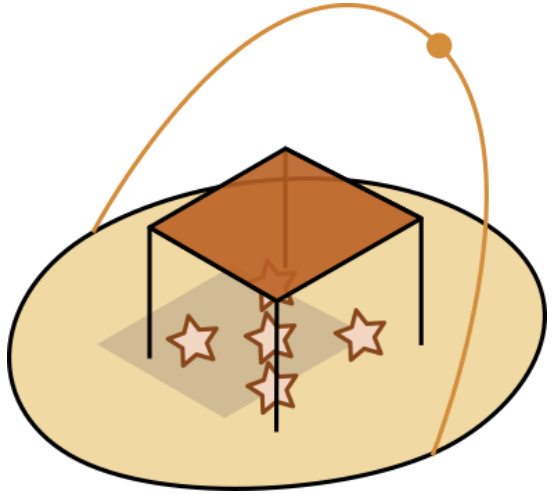



## La projet AbriCoCoDA

*Couvert arboré continu*



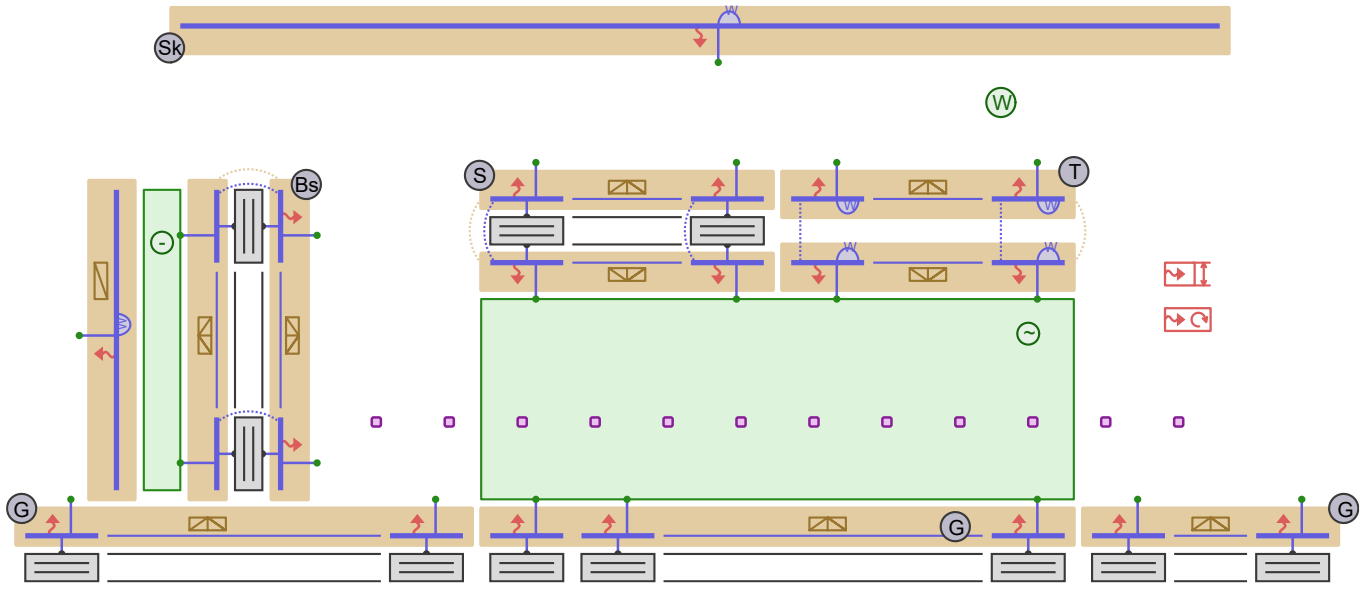
*Abri bâti*

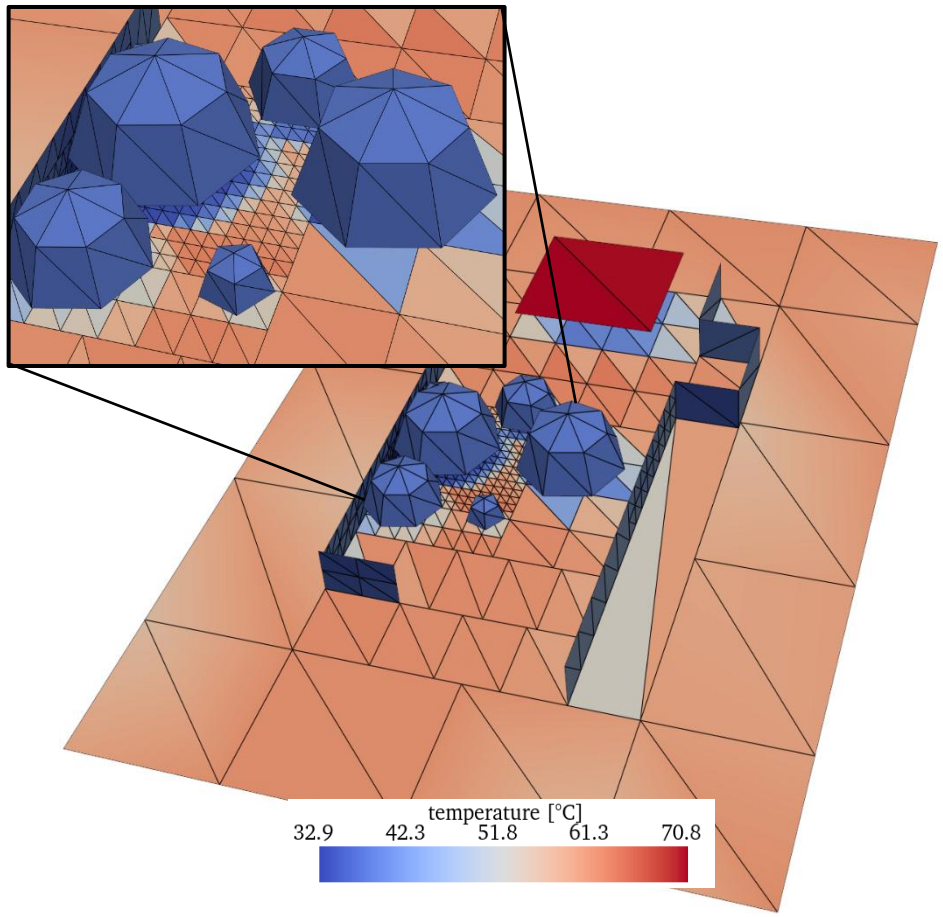


**Au moins aussi confortable que…**

# Contexte

IMOTEP
Micro-Meteorological Model for Outdoor Thermal Environment Perception



## Validation expérimentale

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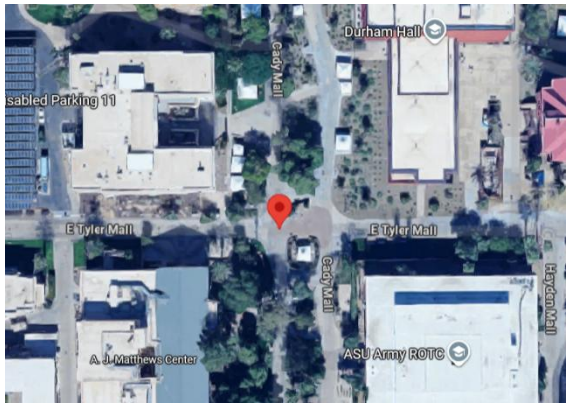
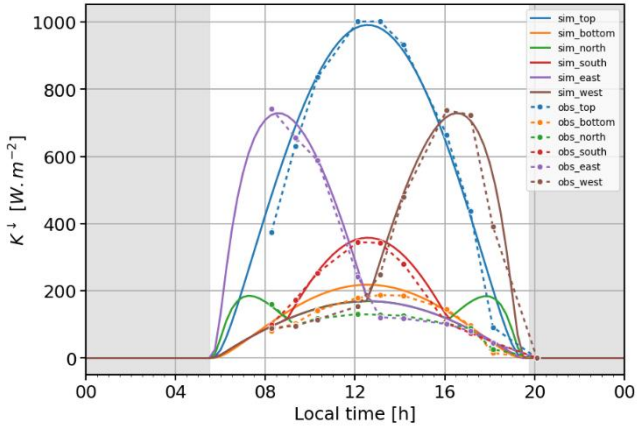
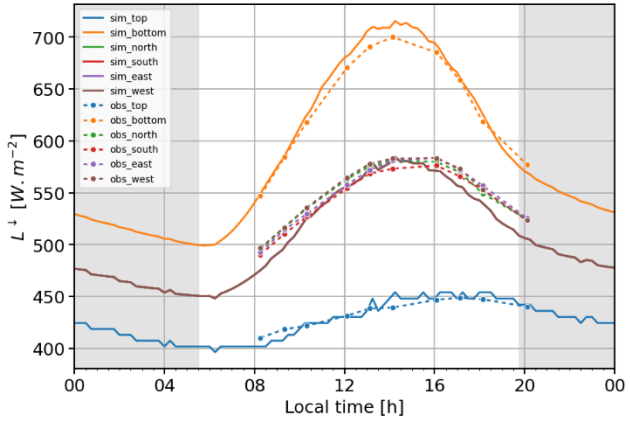
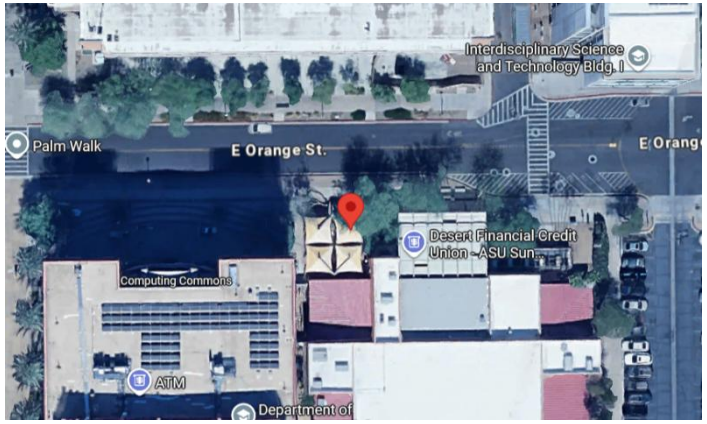
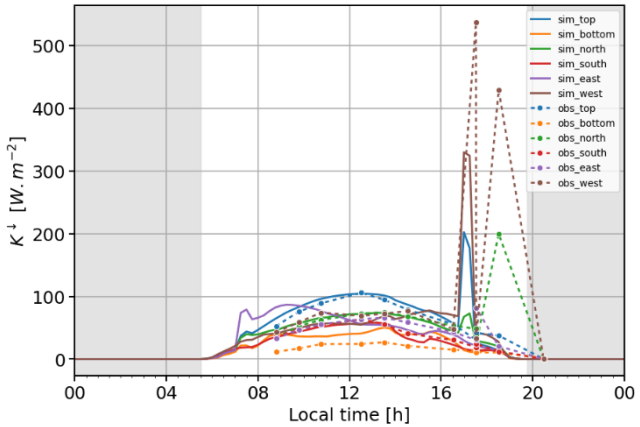
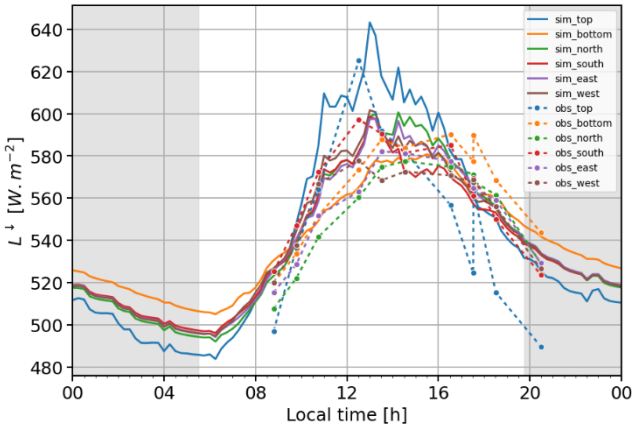


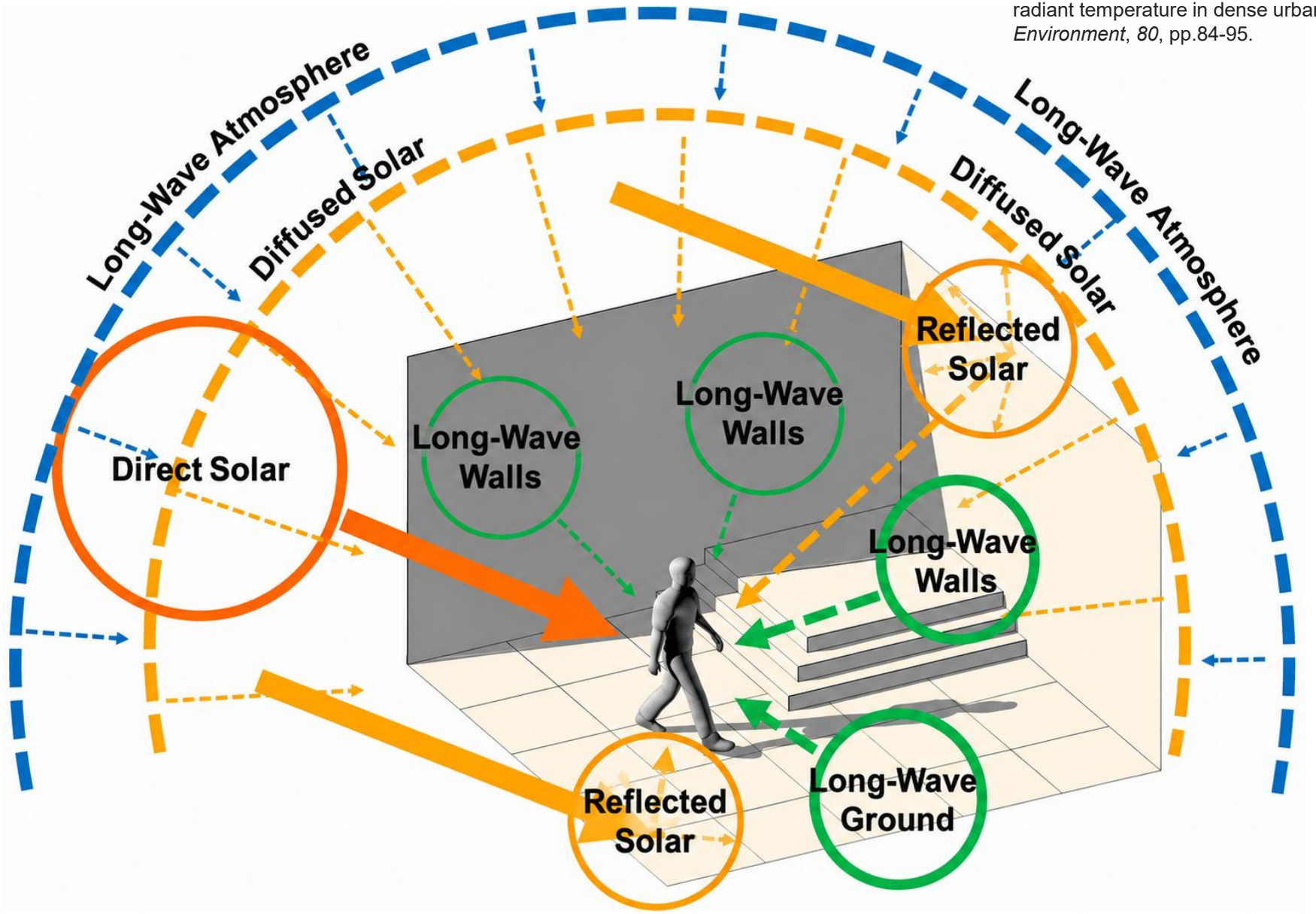



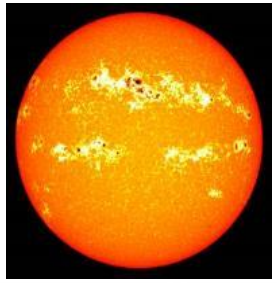



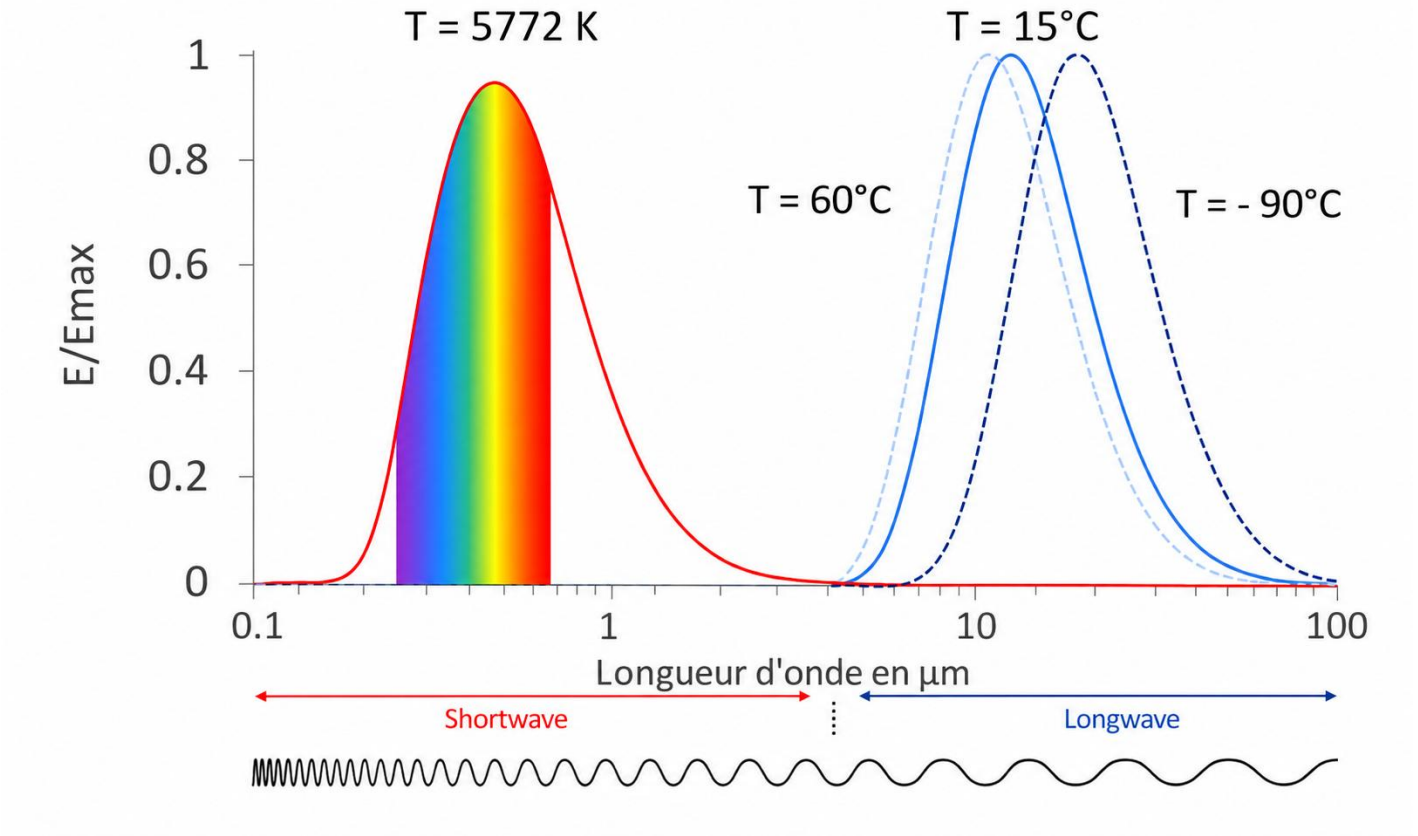
## Confort thermique d'un piéton

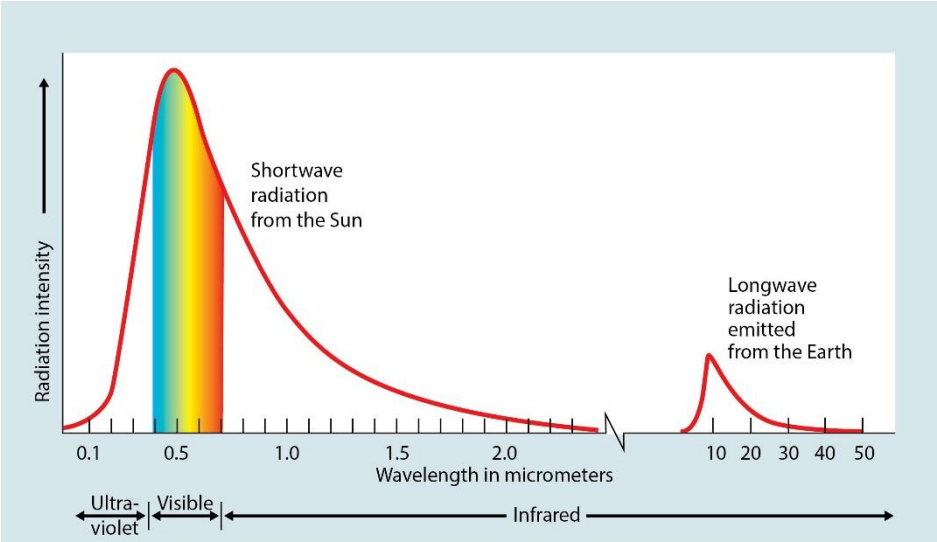
Huang, J., Cedeño-Laurent, J.G. and Spengler, J.D., 2014. CityComfort+: A simulation-based method for predicting mean radiant temperature in dense urban areas. *Building and Environment*, *80*, pp.84-95.

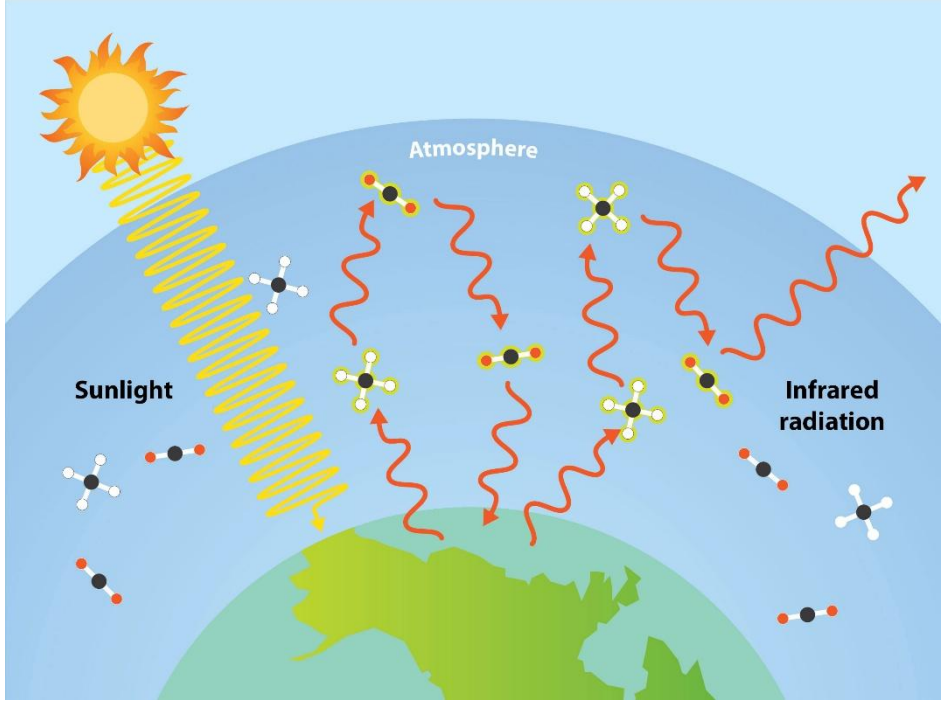


## Le rayonnement thermique

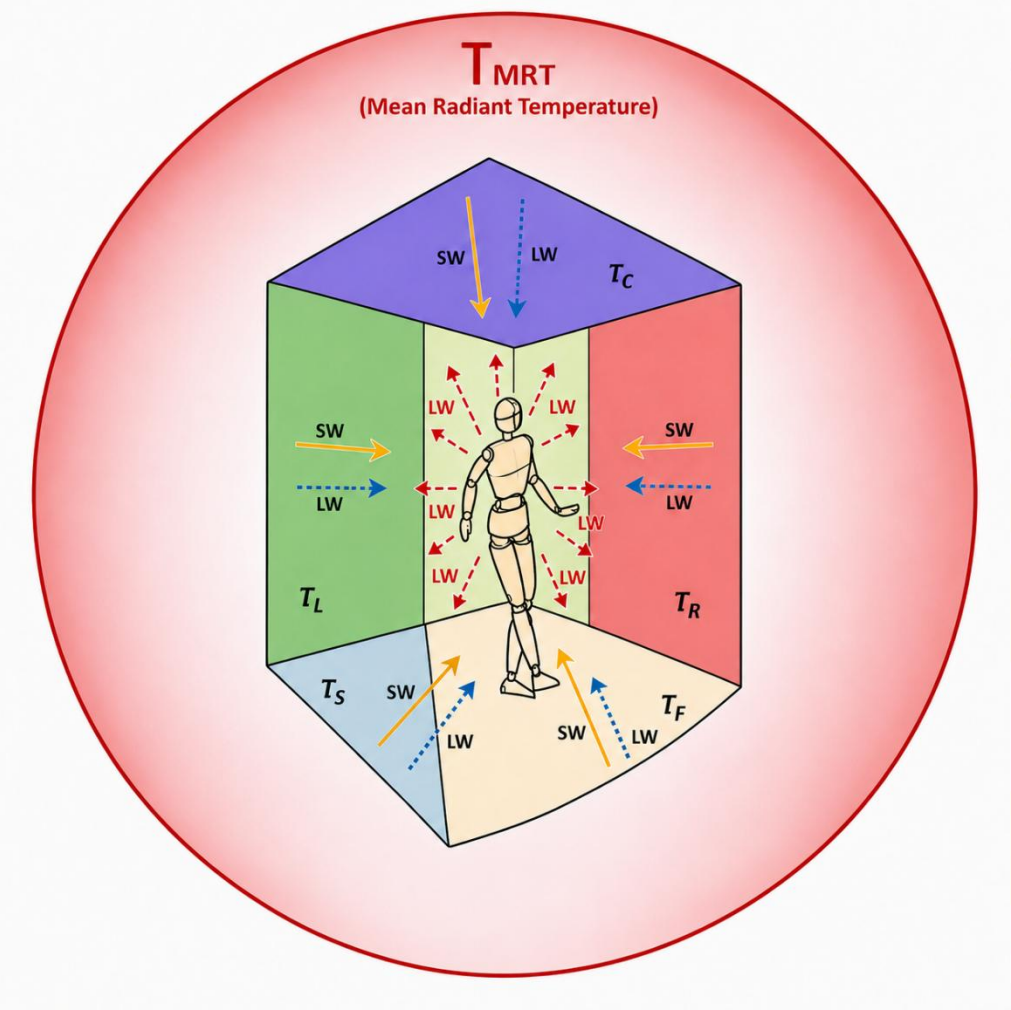


## Température radiante moyenne (mean radiant temperature)




**Environnement radiatif**

$$T_{MRT} = \left[ \frac{\sum_{i=1}^{6} W_i \, (a_k \, K_i + a_l \, L_i)}{a_l \, \sigma} \right]^{\frac{1}{4}} - 273.15$$

**Définition des paramètres**

- $T_{MRT}$ : température radiante moyenne
- $W_i$ : facteur angulaire
- $K_i$ : flux solaire → capté par PYR
- $L_i$ : flux infrarouge → capté par PYG

- UP/DOWN : $W = 0.06$
- Latérales : $W = 0.22$

**Principe : bilan radiatif**

$\Phi$ entrée = $\Phi$ sortie

**$\Phi$ entrée**

$$\sum_{i=1}^{6} W_i \, (a_k \, K_i + a_l \, L_i)$$

**$\Phi$ sortie**

$$a_l \times \sigma \times (TMRT + 273{,}15)^4$$



Enescu, D., 2017. A review of thermal comfort models and indicators for indoor environments. *Renewable and Sustainable Energy Reviews*, *79*, pp.1353-1379.

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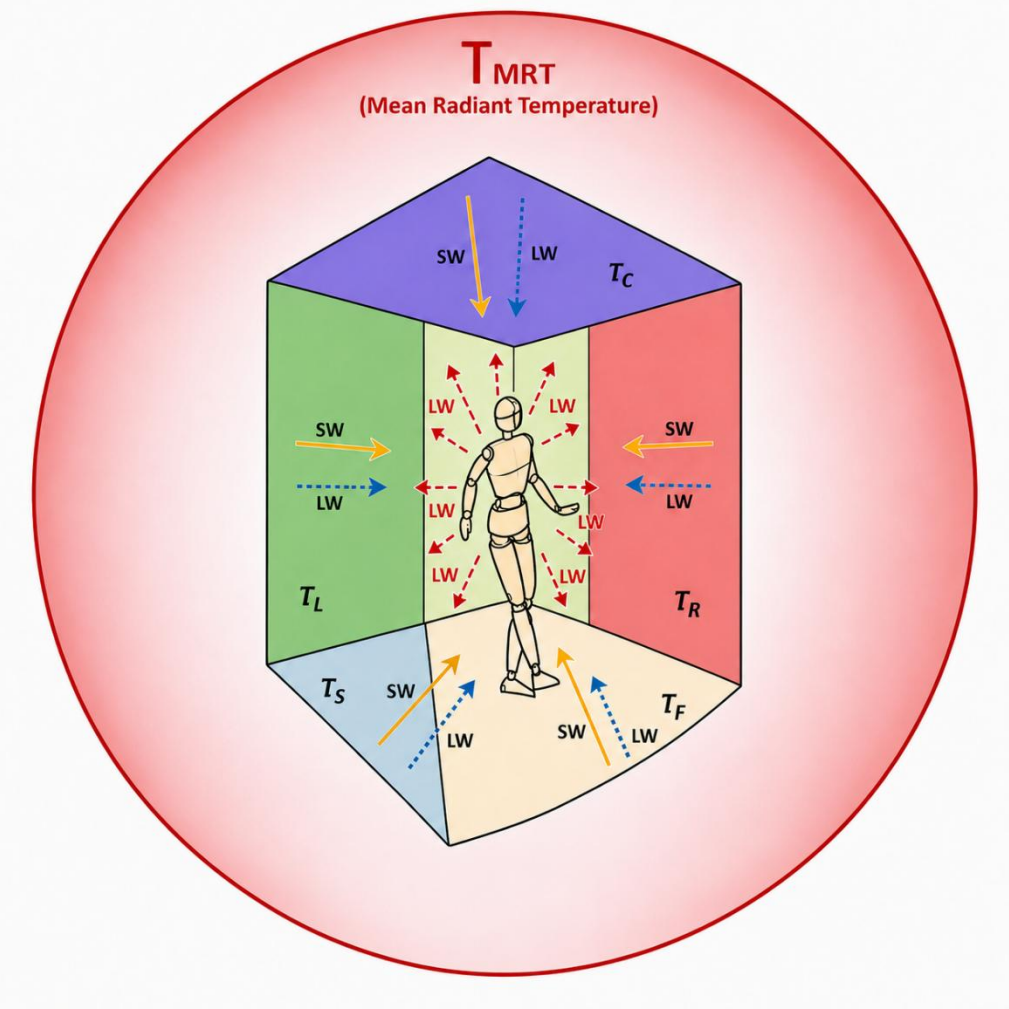
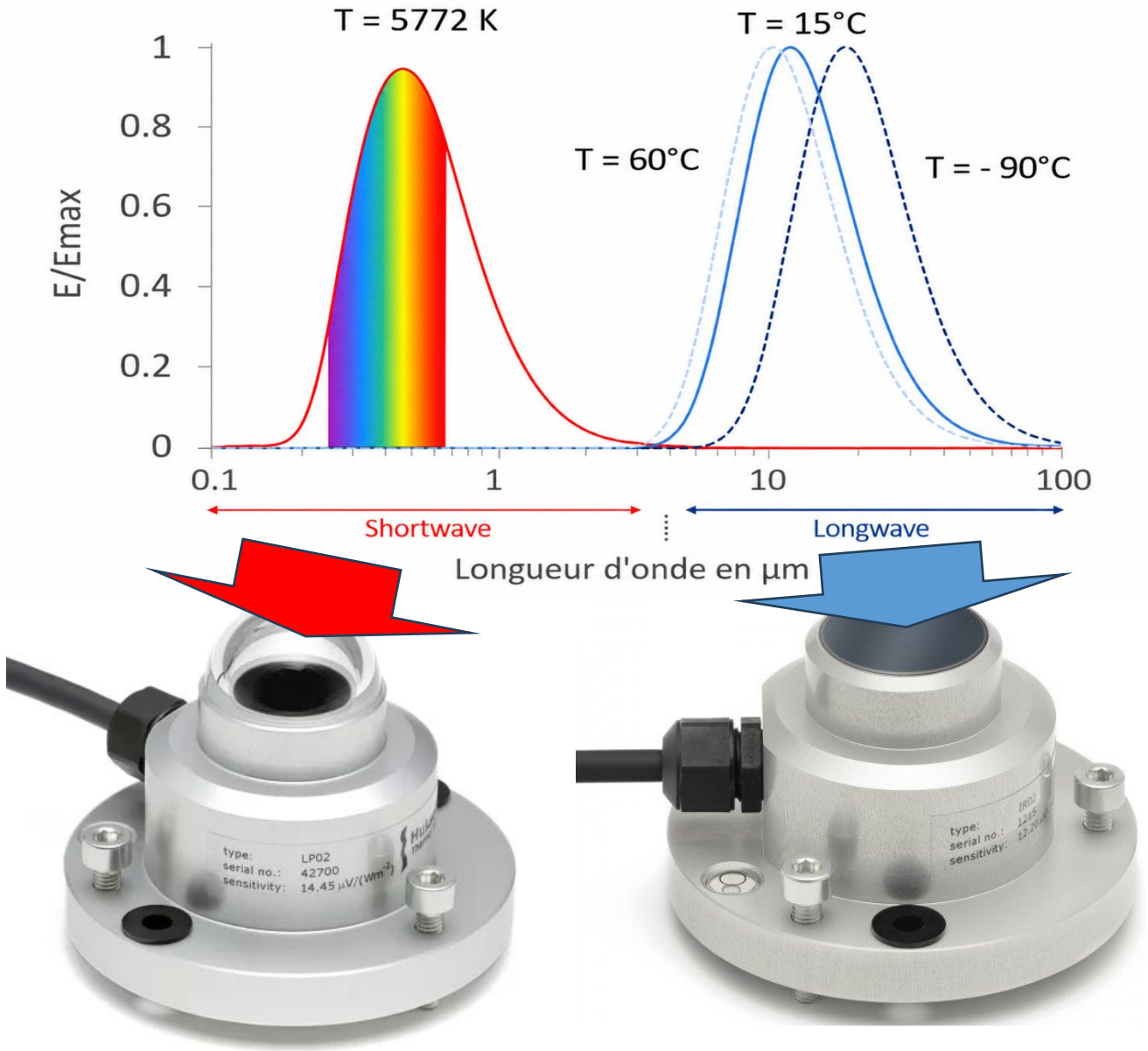
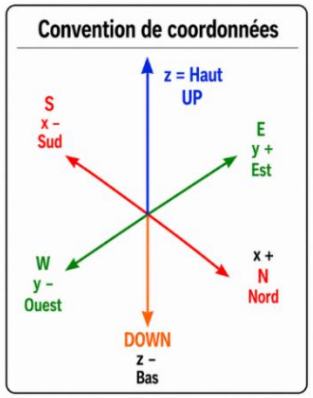



**Environnement radiatif**



## 6 Capteurs pyranomètres + 6 capteurs pyrgéomères

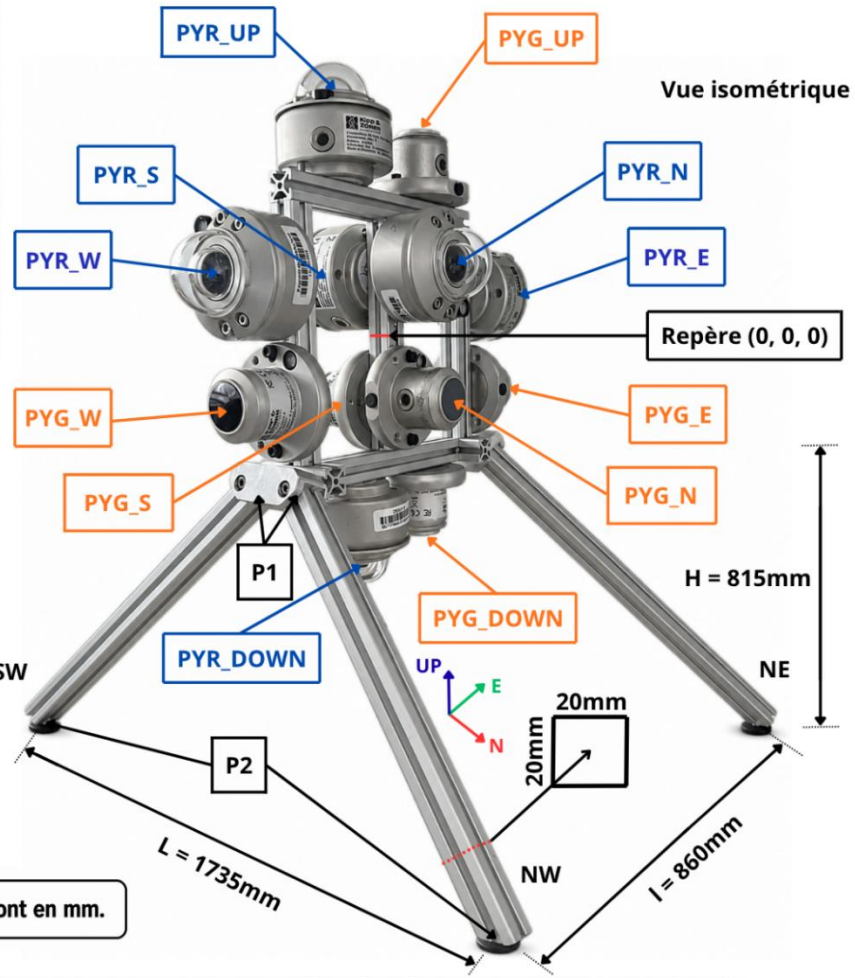



Chaque direction comporte 1 pyranomètre et 1 pyrgéomètre.

(12 capteurs au total)

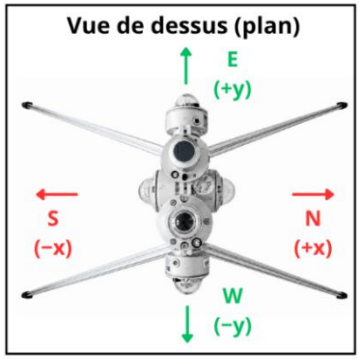
PYR : pyranomètre

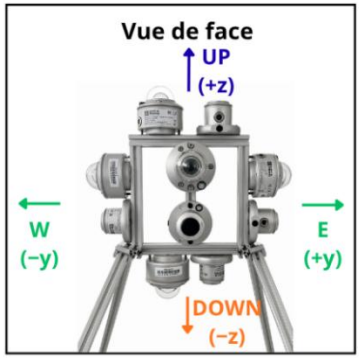
PYG : pyrgéomètre

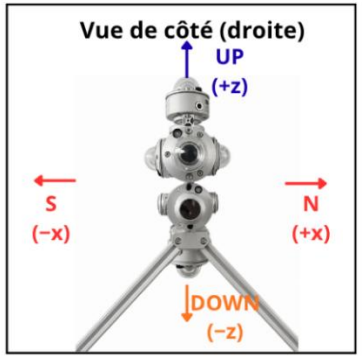



Toutes les coordonnées sont en mm.

Le repère O (0,0,0) est placé au centre entre les pyranomètres N/S et les pyrgéomètres N/S.

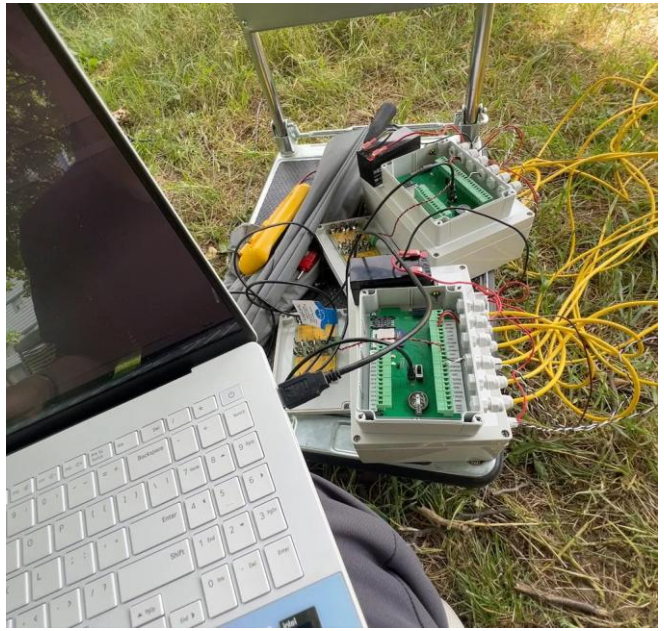


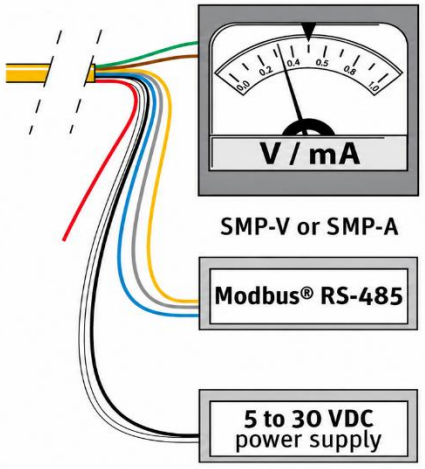



# Dispositif

## 6 Capteurs pyranomètres + 6 capteurs pyrgéomères

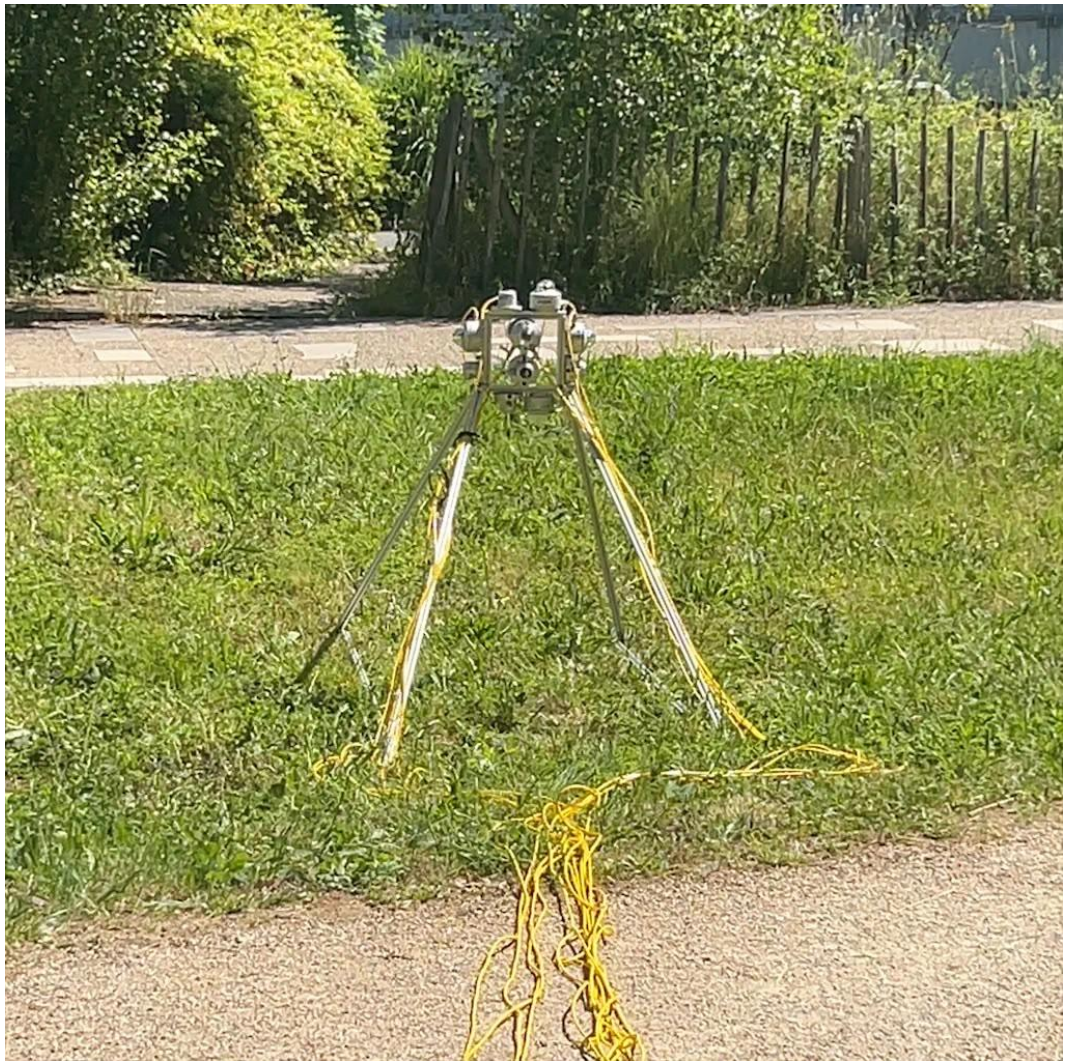



**Radiometer Connection**

| Wire | | Function | Connect with |
|---|---|---|---|
| 3 | Green | Analogue out | V+/4-20 mA(+) |
| 6 | Brown | Analogue ground | V–/4-20 mA(–) |
| 4 | Yellow | Modbus® RS-485 | B/B'/+ |
| 5 | Grey | Modbus® RS-485 | A/A'/– |
| 7 | White | Power 5 to 30 VDC (12 V recommended) | |
| 8 | Black | Power ground / RS-485 Common | |
| 1 | Red | None | Not connected |
| 2 | Blue | Modbus® common / Ground | |
| | Shield | Housing | Ground * |

* Connect to ground if radiometer not grounded

## Premier essai à l'extérieur



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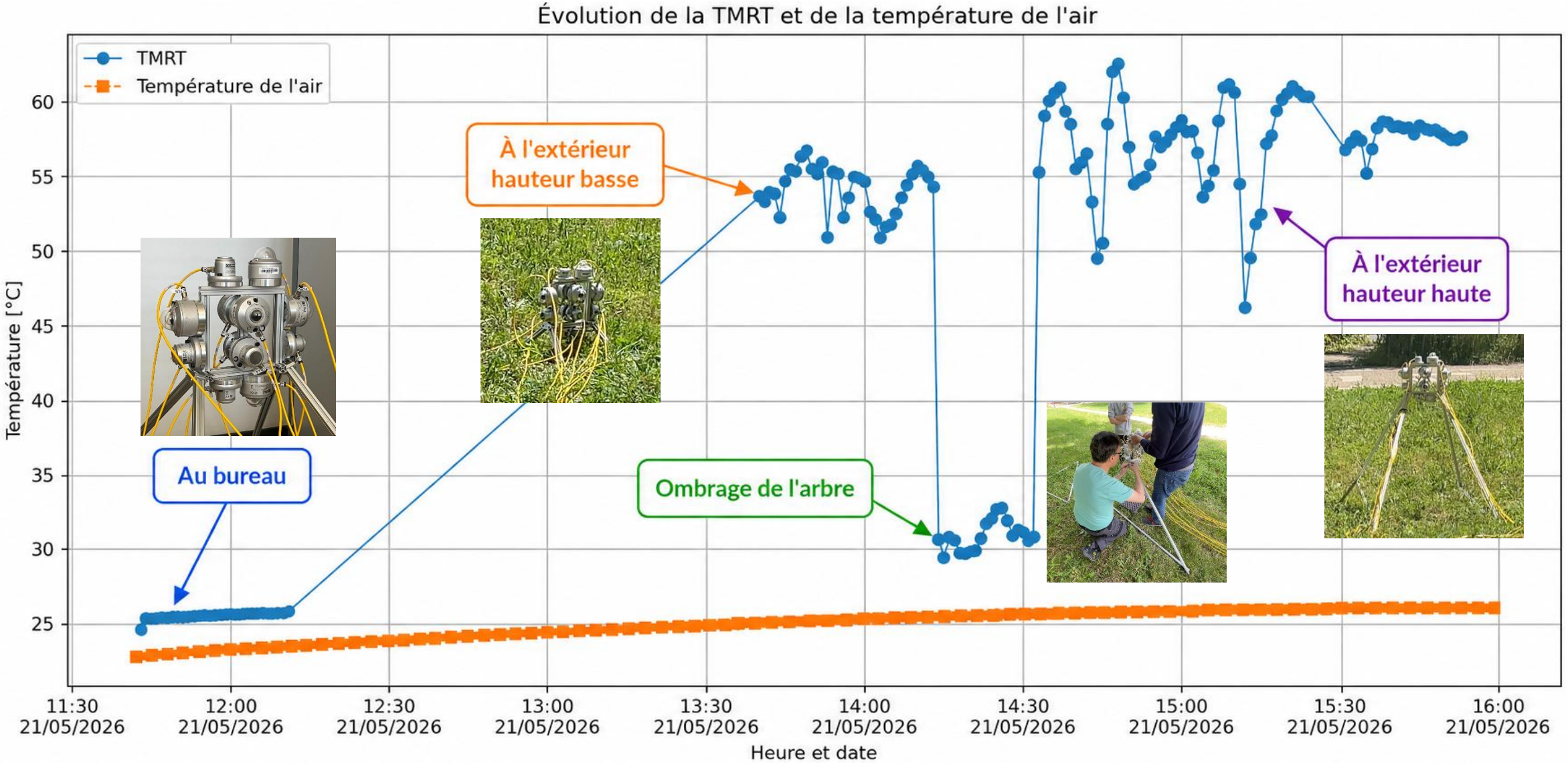
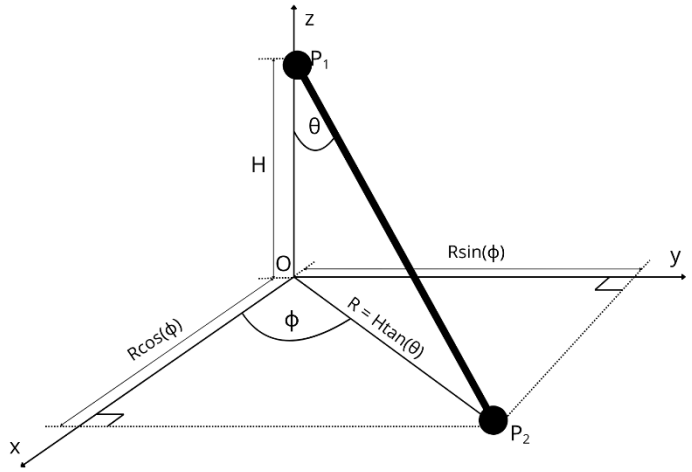


## Optimisation de la configuration du système

$$P_2 = (H\tan(\theta)\cos(\phi), H\tan(\theta)\sin(\phi), z)$$

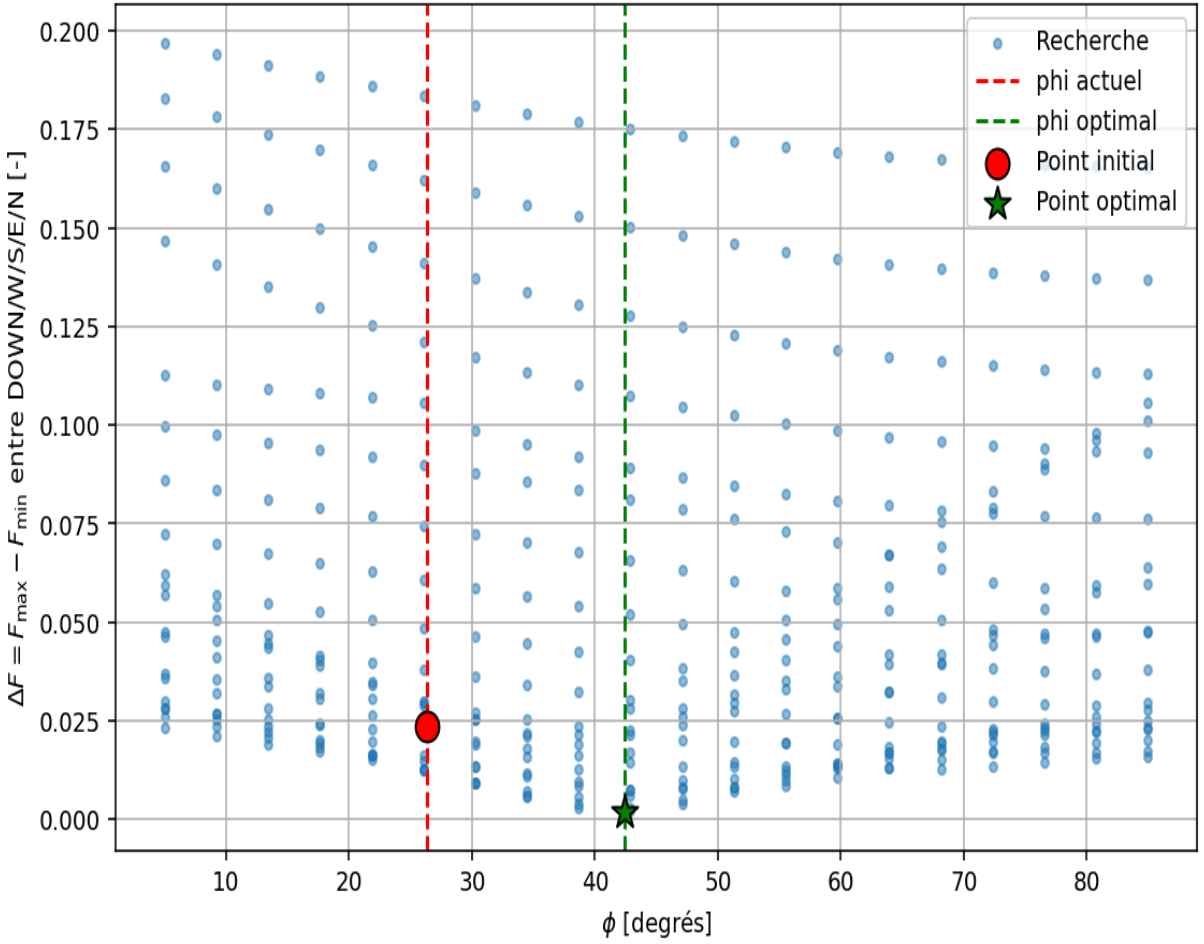


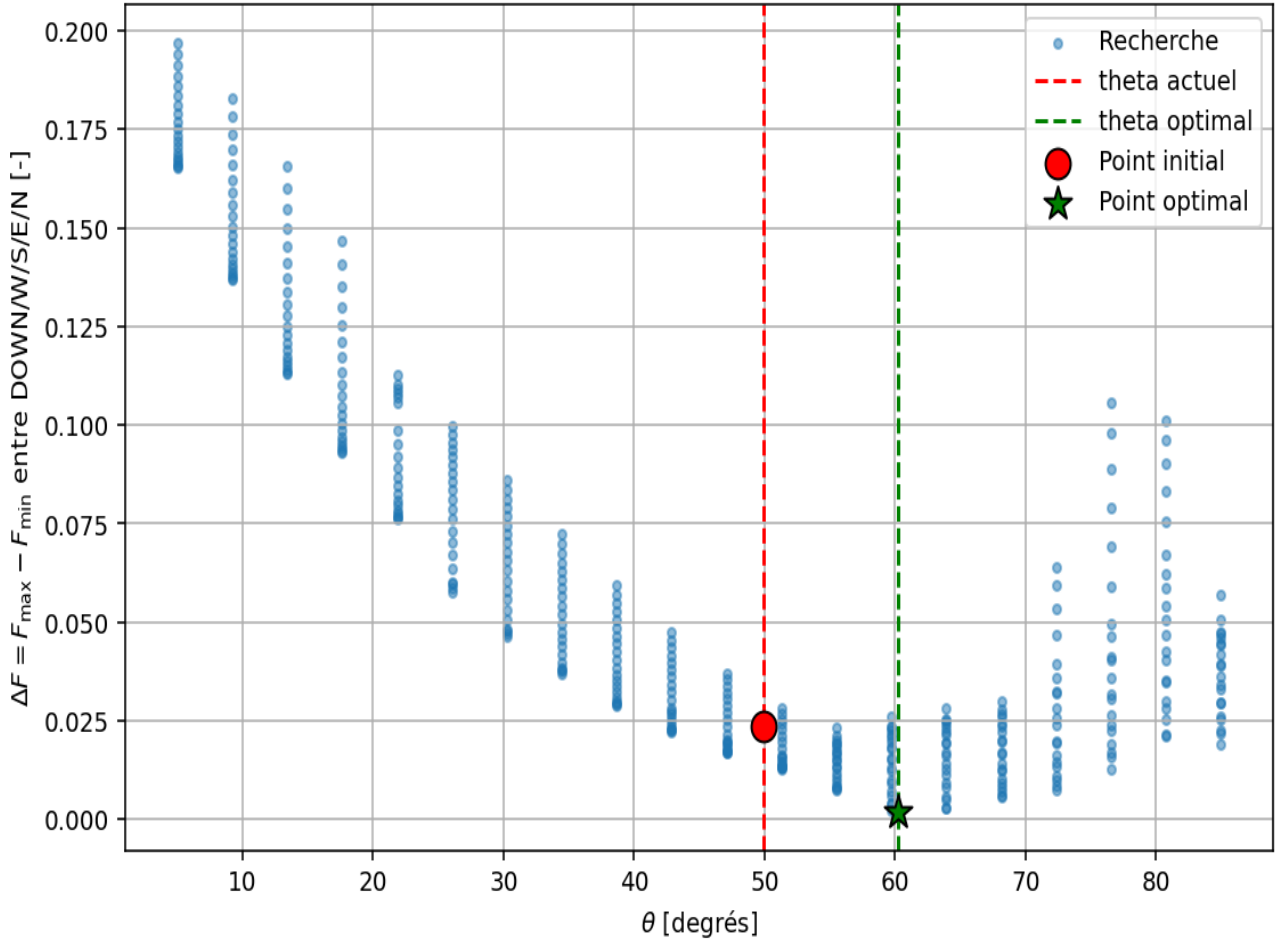




$$F_{capteur \to pied} \simeq \sum_{j=1}^{N} \frac{\cos\theta_{capteur,j}\cos\theta_{pied,j}}{\pi\left\|\overrightarrow{P_0P_j}\right\|^2}\Delta A_j$$

## Optimisation de la configuration du système



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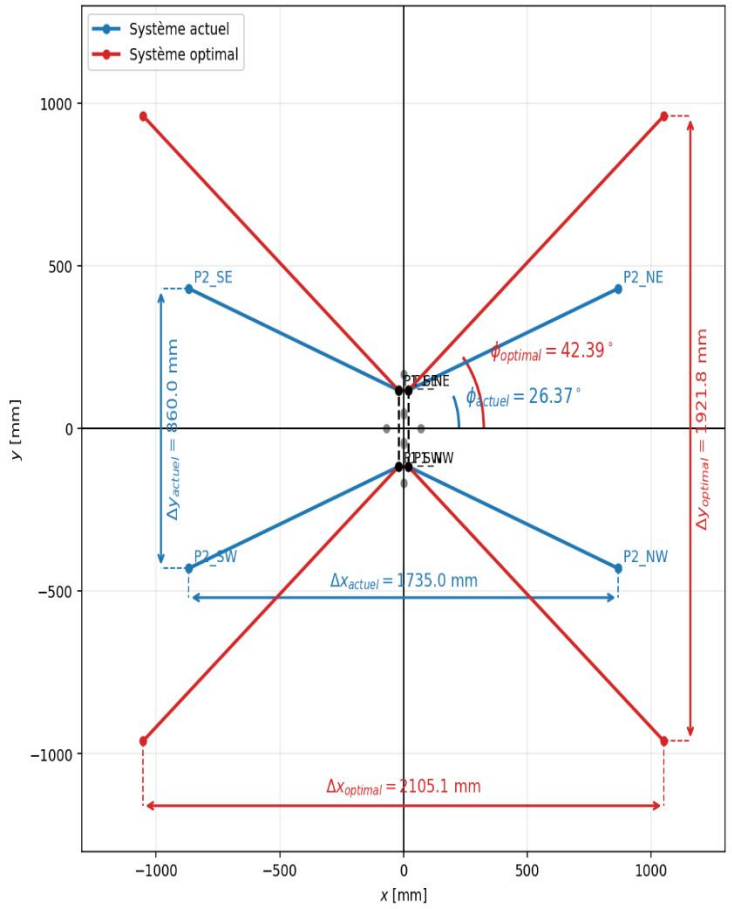
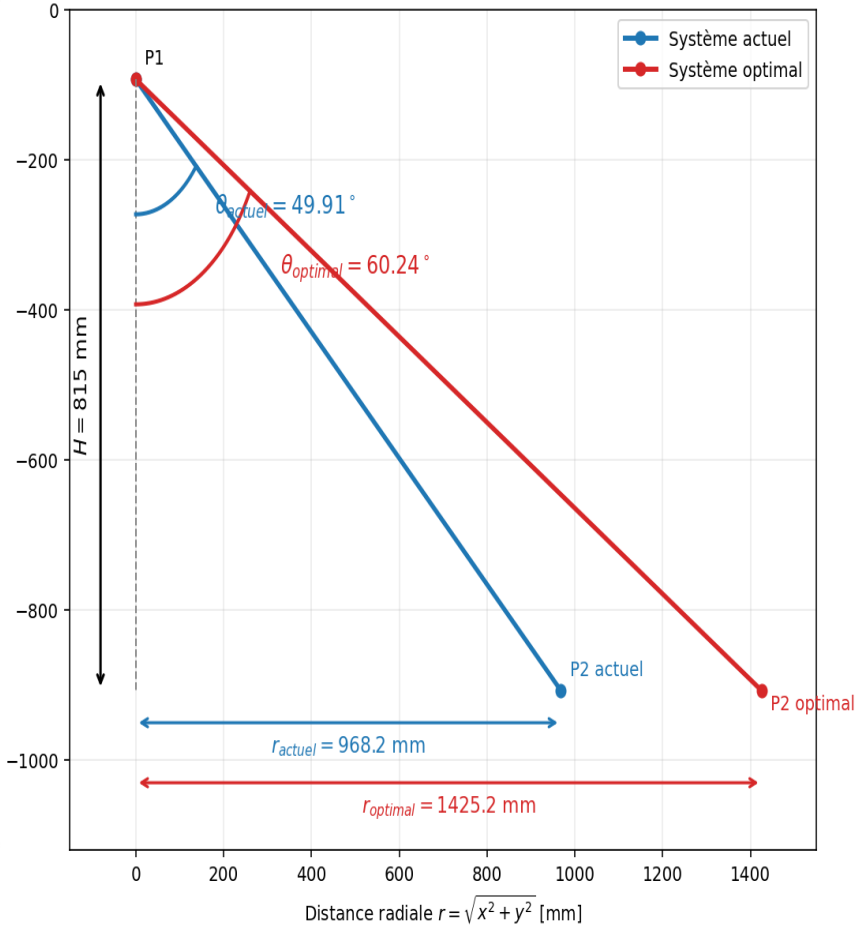
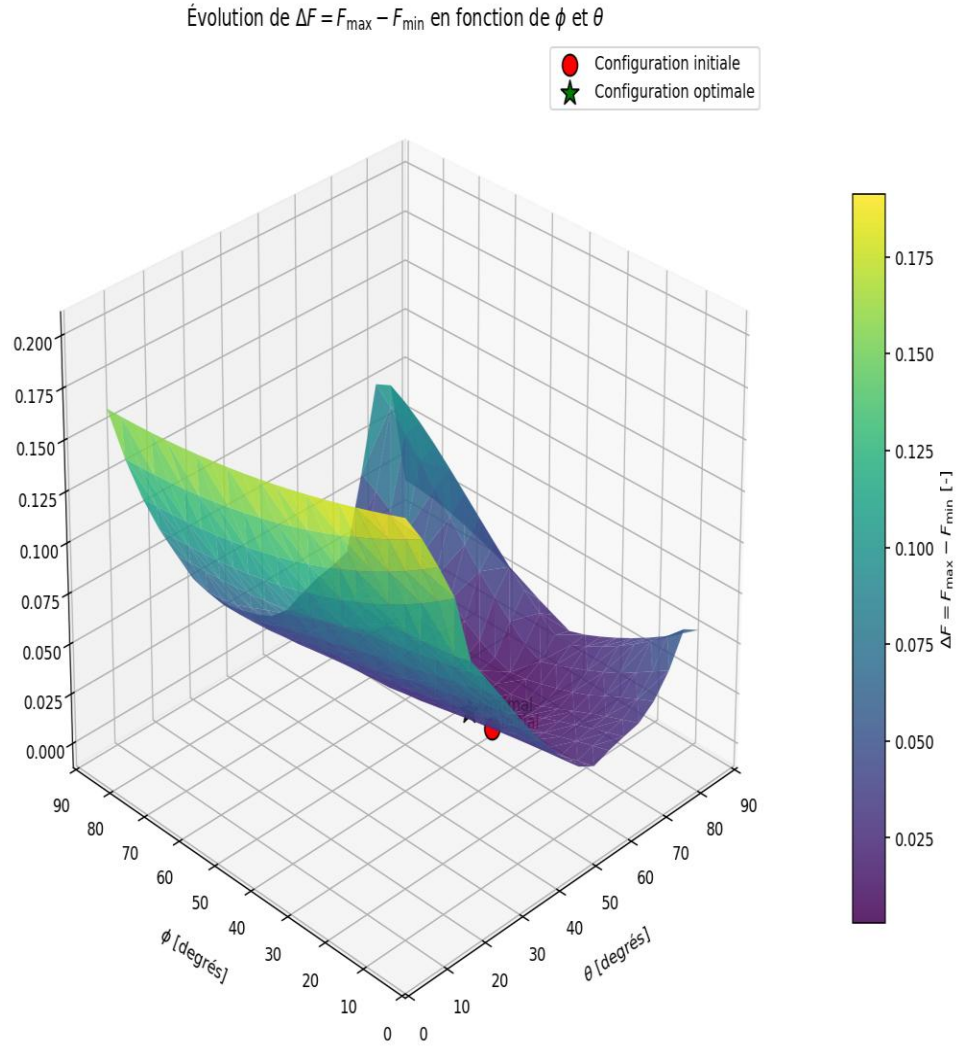


## Optimisation de la configuration du système

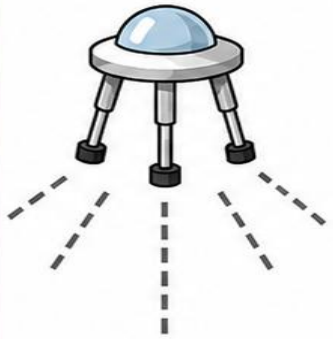
### Cas initial

1. Facteurs de forme moyens par direction

| Direction | Facteur de forme moyen | Champ de vision occupé |
|---|---|---|
| DOWN | 0.0246 | 2.46 % |
| W | 0.0009 | 0.09 % |
| S | 0.0102 | 1.02 % |
| E | 0.0009 | 0.09 % |
| N | 0.0102 | 1.02 % |

2. Statistiques globales

| | |
|---|---|
| Moyenne | 0.0093 |
| Champ de vision maximal | 2.46 % |
| Angles initiaux | $\phi_{init} = 26.4°$ ; $\theta_{init} = 49.9°$ |



Optimisation

### Cas optimal

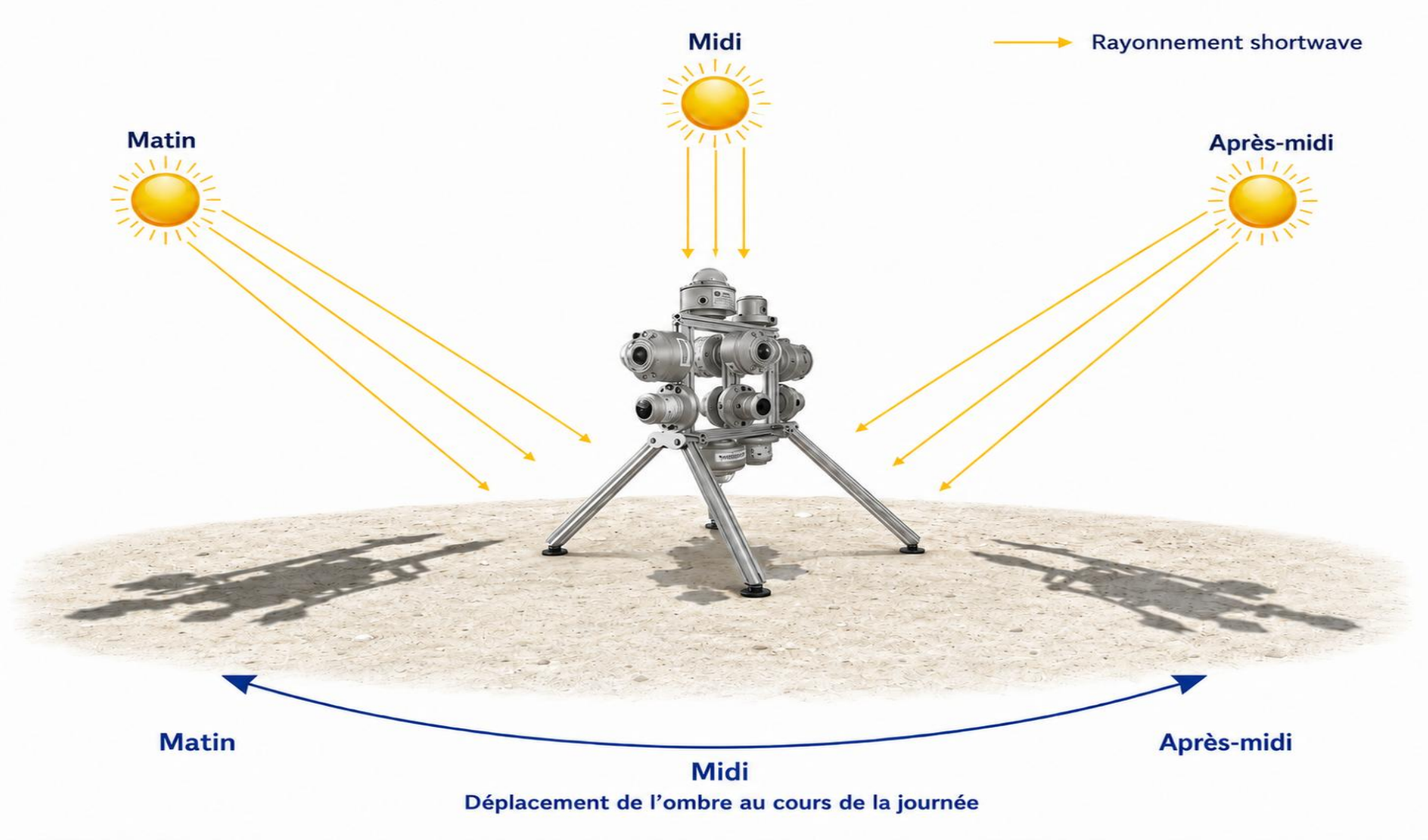
1. Facteurs de forme moyens par direction

| Direction | Facteur de forme moyen | Champ de vision occupé |
|---|---|---|
| DOWN | 0.0091 | 0.91 % |
| W | 0.0072 | 0.72 % |
| S | 0.0071 | 0.71 % |
| E | 0.0072 | 0.72 % |
| N | 0.0071 | 0.71 % |

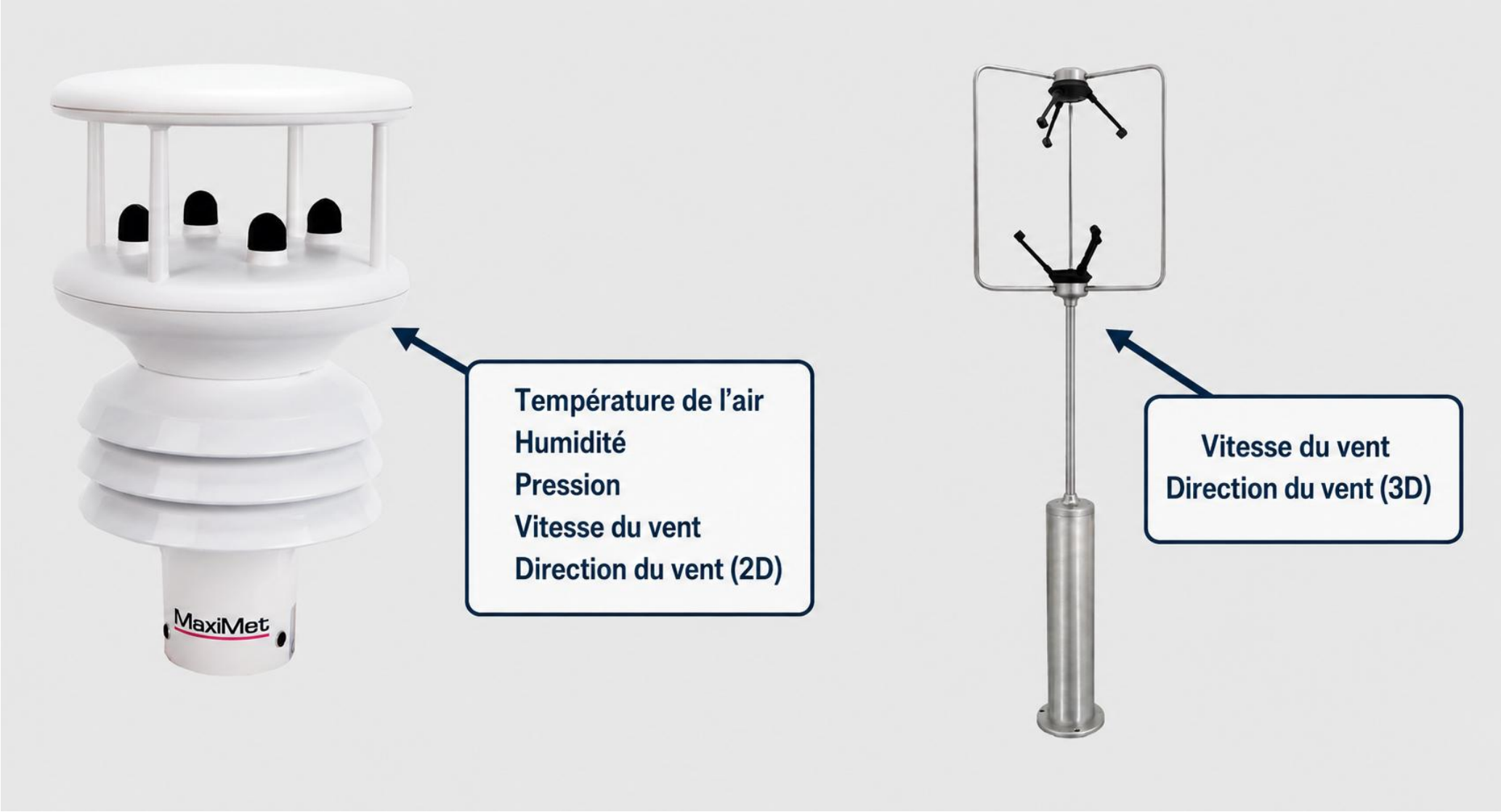
2. Statistiques globales

| | |
|---|---|
| Moyenne | 0.0075 |
| Champ de vision maximal | 0.91 % |
| Angles optimaux | $\phi_{opt} = 42.4°$ ; $\theta_{opt} = 60.2°$ |

## Optimisation de la configuration du système



## Perspectives



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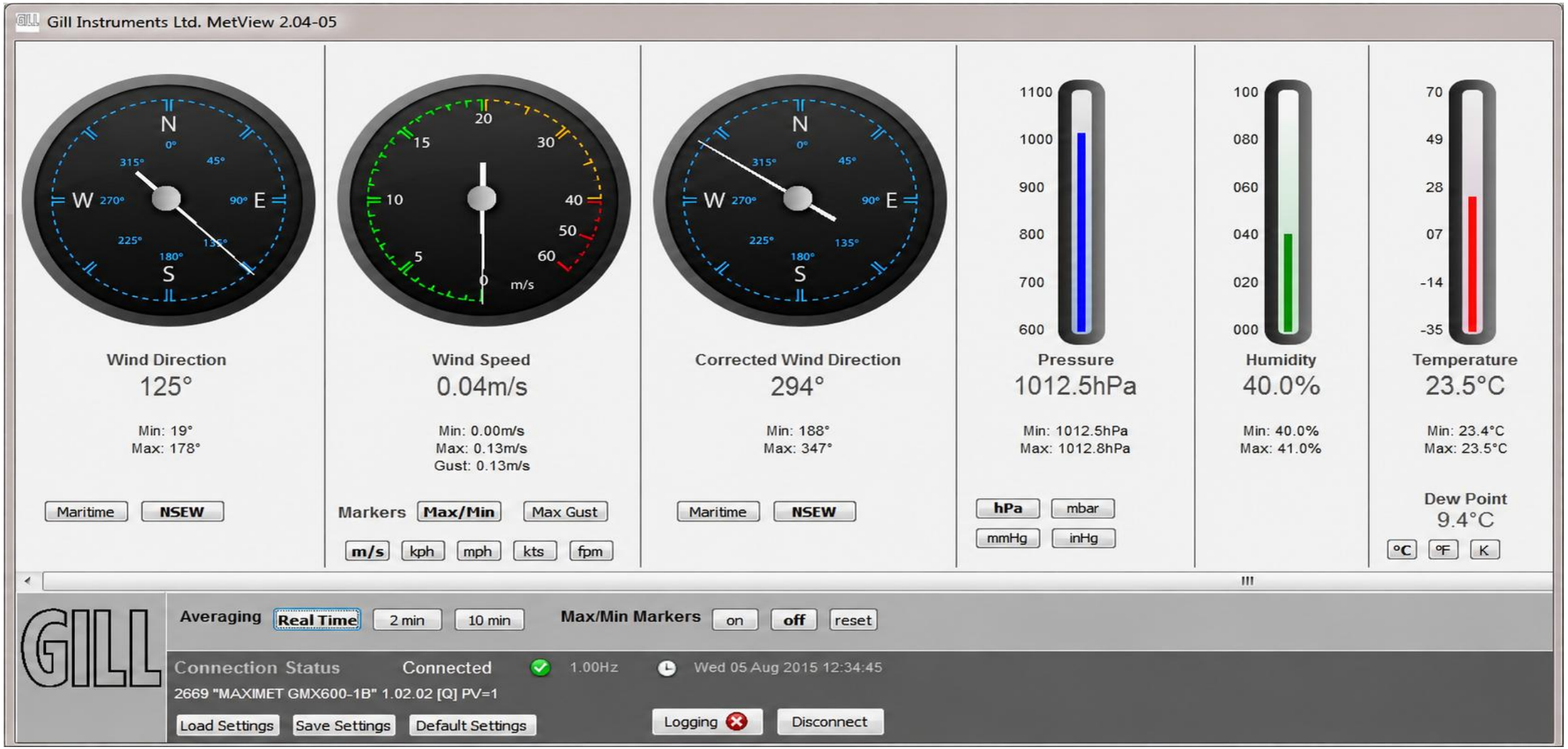

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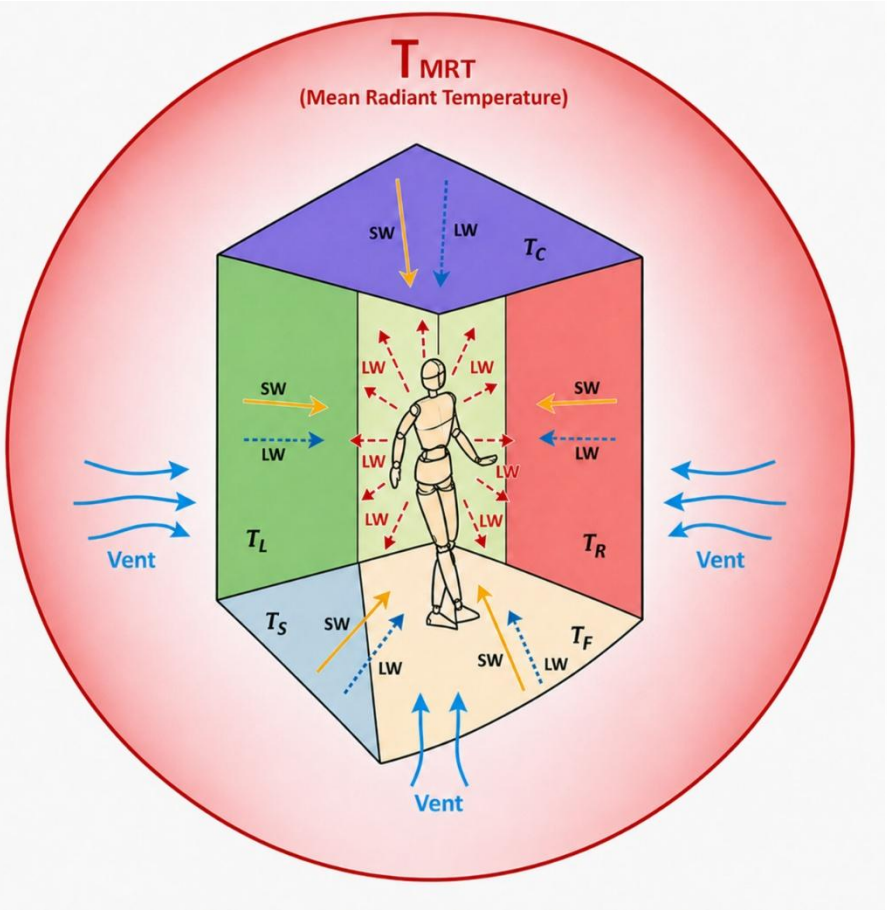


# Température opérative

$$T_o = \frac{T_{mrt} + T_a \sqrt{10\, V_{vent}}}{1 + \sqrt{10\, V_{vent}}}$$

*Intégration de la vitesse du vent mesurée par le capteur*

- $T_o$ : température opérative [°C]
- $T_{mrt}$ : température radiante moyenne [°C]
- $T_a$ : température de l'air [°C]
- $V_{vent}$ : vitesse du vent mesurée par le capteur [$m \cdot s^{-1}$]

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## Perspectives

**GARE DE LYON-PART-DIEU**

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