

Understanding the urban climate interactions from city block to agglomeration scale : the PANAME experiment over the Paris region (France)

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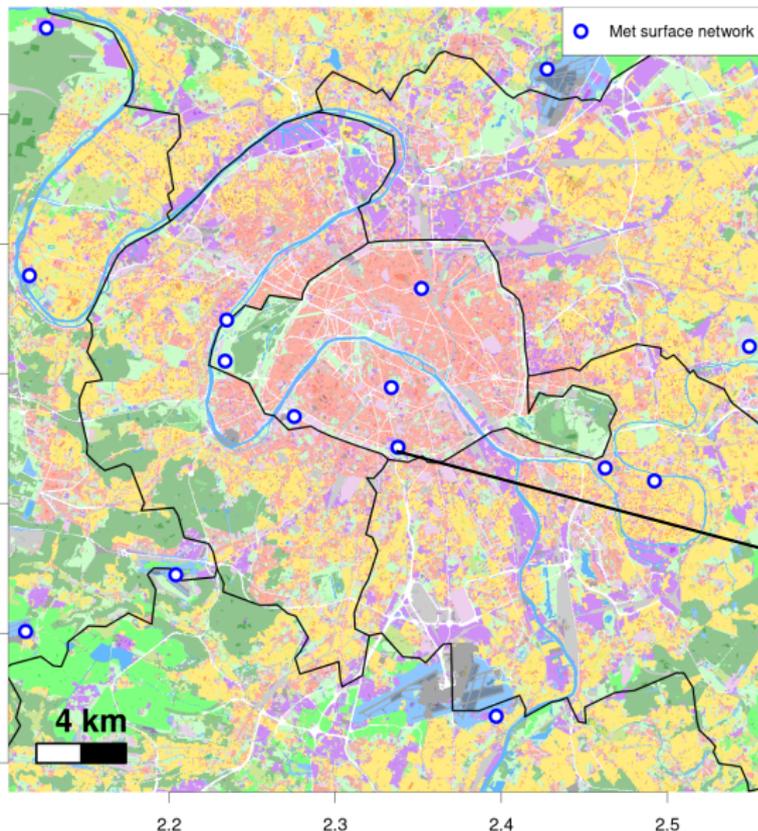
Sub-km NWP & the need of high resolution measurements

As modellers we use observational data for three main reasons:

- process studies (to develop models)
- verification of model output (routinely and for research)
- data assimilation

Going toward hectometric scale NWP is very challenging because high impact phenomena may manifest in rather small spatial and temporal scales. There are few observation sources that have the spatial resolution required for hectometric modelling.

Sub-km NWP & the need of high resolution measurements



- National meteorological services operational observation network have generally sparse density. It is an issue across large cities.
- Appropriate meteorological variables measurements guidelines in the urban environment are in contradiction with WMO ones (Oke, 2004).



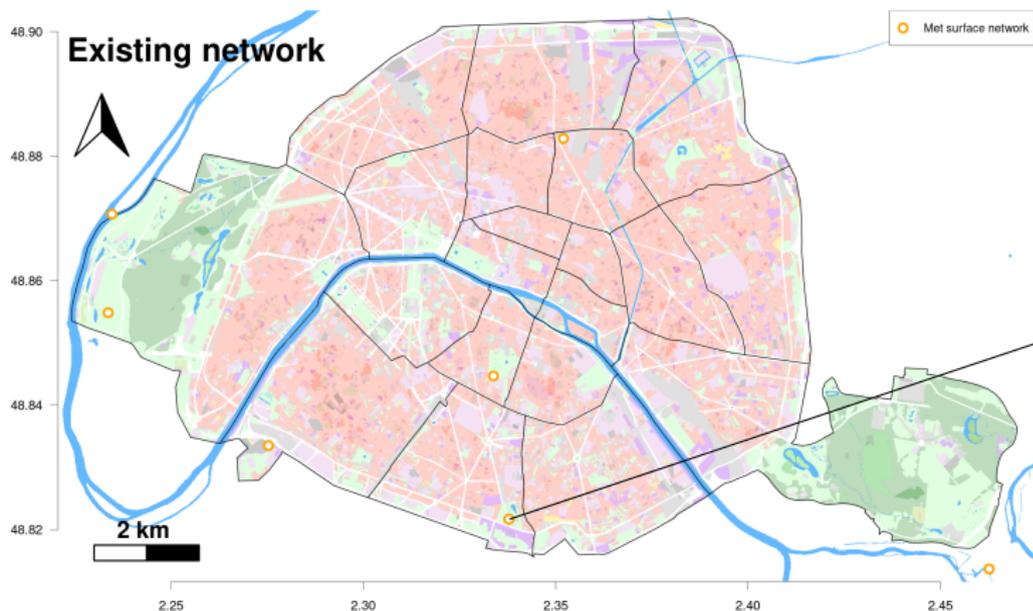
There is a need of high resolution measurements across cities to improve our understanding of the urban climate and to evaluate hectometric models

There is a need of high resolution measurements across cities to improve our understanding of the urban climate and to evaluate hectometric models

- The PANAME experimental campaign across the Paris region.
- Urban climate interactions between city blocks and urban parks
- The hectometric meteorological research model Meso-NH and its ability to capture small-scale heterogeneities processes in cities
- PANAME data as reference for model intercomparison at the agglomeration scale
- Forecasting application: Marathon for All

PANAME experimental campaign (2022-2024)

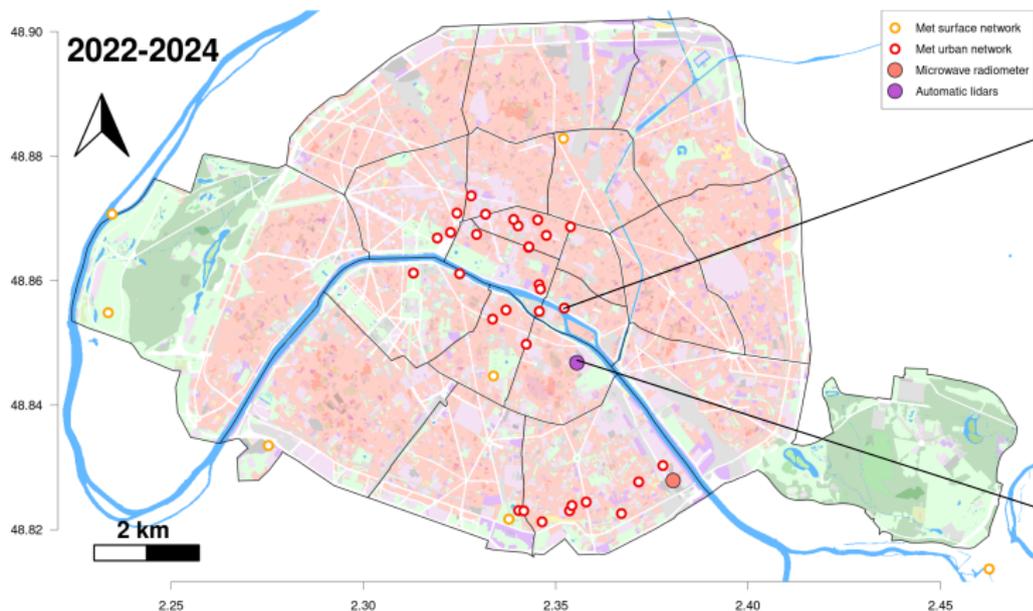
PANAME (Paris region urbaN Atmospheric observations and models for Multidisciplinary rEsearch Intensive): Improve our understanding of the urban climate, its spatial (horizontally and vertically) and temporal variability, and its link to local meteorology, using multi-source and multi-scale observations.



Taking Paris region as case study.

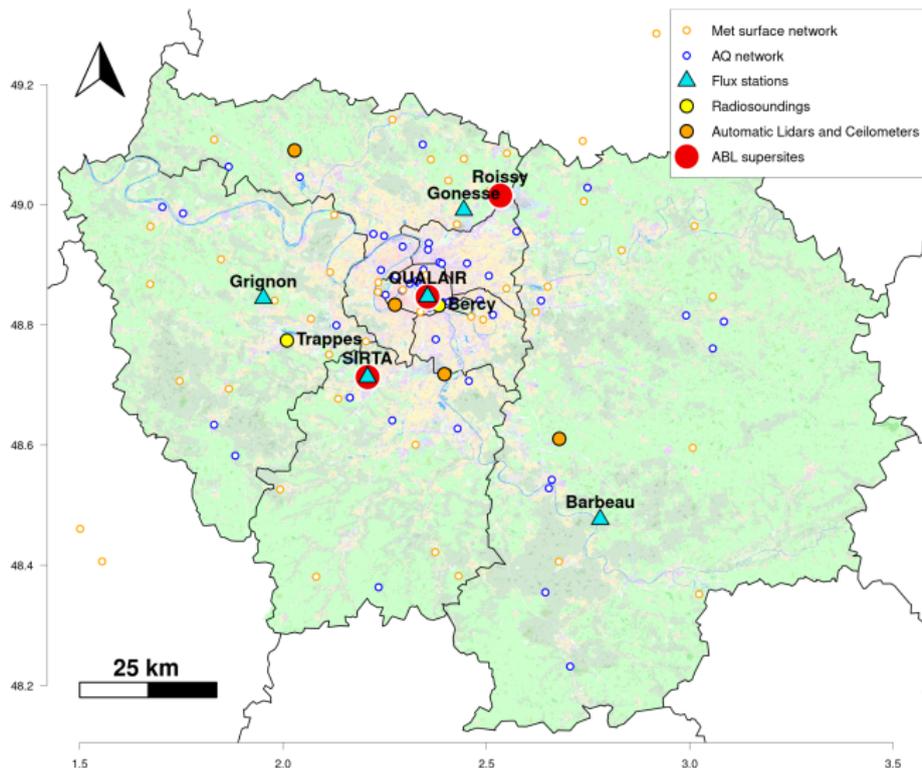
PANAME experimental campaign (2022-2024)

Existing institutional observation networks have been reinforced by long-term in-situ and remote sensing measurements. Acquisition of meteorological variables at the surface and vertical profiles of thermodynamic parameters in the atmospheric boundary layer.



PANAME experimental campaign (2022-2024)

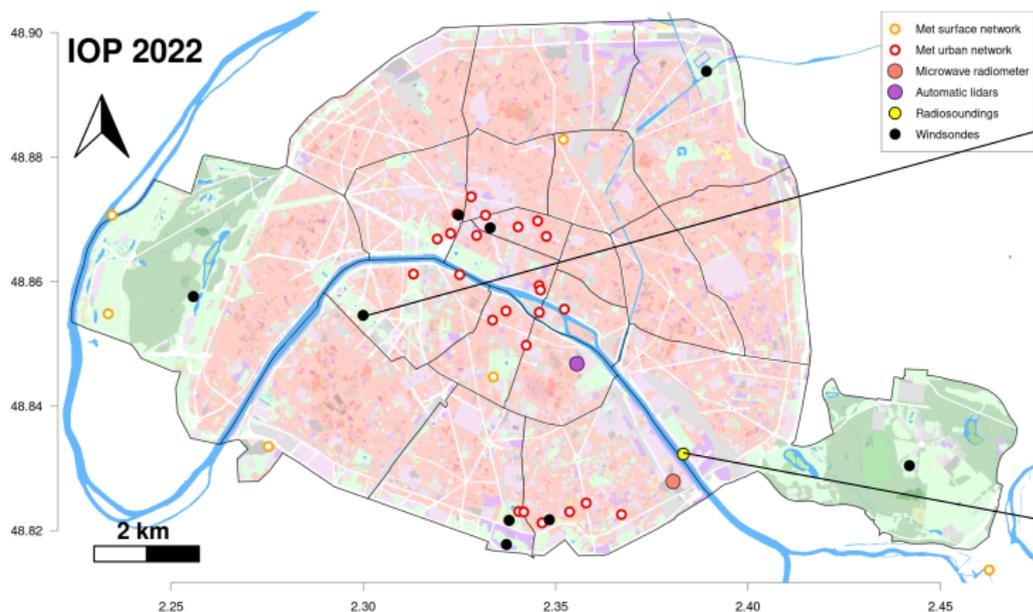
Observation networks reinforcement also done over Ile-de-France region.



Data available soon on Aeris: <https://paname.aeris-data.fr/data-catalogue-2/>

PANAME experimental campaign (2022-2024)

Summer 2022 intensive observation phase (IOP): document the cooling phase at the end of the day and beginning of the night, by combining ABL soundings from different locations (urban areas and urban parks)



Adapted from Lemonsu et al. (submitted to BAMS)

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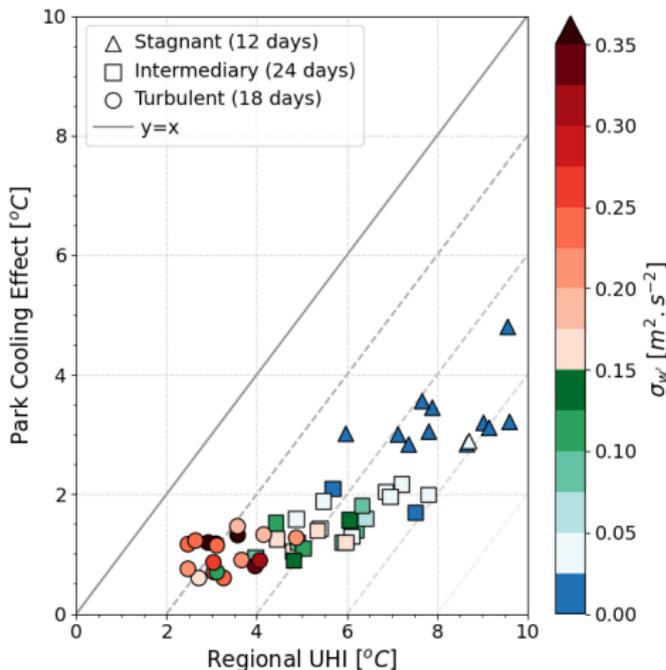
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September 30, 2024

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2022 IOP: Impact of vertical mixing conditions on urban park cooling

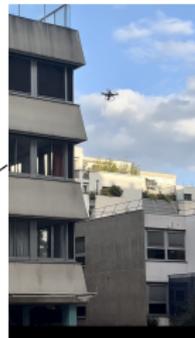
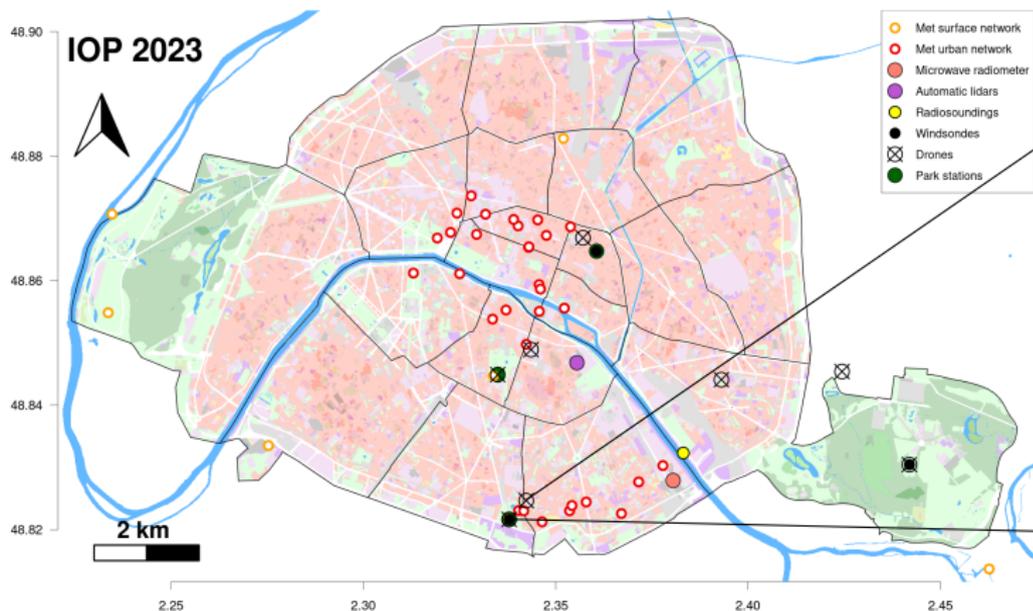
- Cespedes et al. (2024): Wind vertical velocity variance ($\sigma_{w'}$ - measured with Doppler lidar) is strongly correlated with UHI intensity.
- Haeffelin et al. (ACPD 2024): $\sigma_{w'}$ good proxy for turbulent vertical mixing conditions. We can distinguish 3 different evening cooling regimes for clear-sky days in the urban environment:
 - Turbulent (low park effect): $\sigma_{w'} > 0.25$
 - Intermediary (limited park effect): $0.1 < \sigma_{w'} < 0.25$
 - Stagnant (strong park effect): $\sigma_{w'} < 0.1$



Haeffelin et al. (ACPD 2024)

PANAME experimental IOP July 2023

Focus on the role of urban parks upon microclimate and local cooling:
radiosoundings + windsondes + **semi-permanent ground weather stations in 3 parks + vertical profiles with drones in the evening in 3 parks and 5 urban areas**



Adapted from Lemonsu et al. (submitted to BAMS)

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September 30, 2024

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Drones measurements

- Study late afternoon / evening cooling with simultaneous vertical profiles in park and neighboring urban environment or 2 different parks.
- T, RH and horizontal wind up to 120m (profiles every 30 minutes)
- More than 300 vertical profiles at eight sites in Paris



Semi-permanent ground weather stations

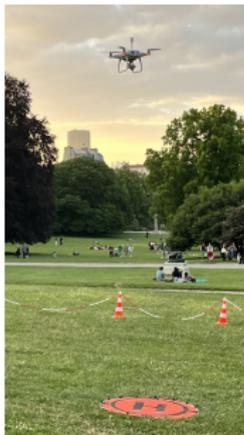
- Continuous measurements inside 3 city parks of various size (0.77, 15.5 and 23 ha) from mid-june 2023 to 2025.
- 2m air temperature, RH and horizontal wind speed + black globe + soil humidity and temperature profiles (10 - 60cm).



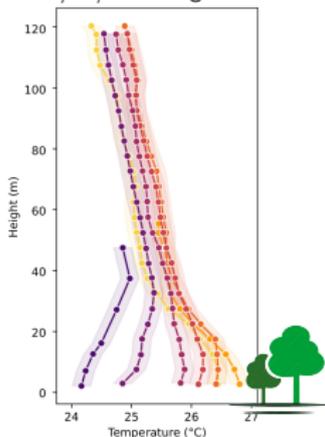
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Urban vs Park cooling: vertical profiles

Montsouris Park



06/07/23 - Stagnant

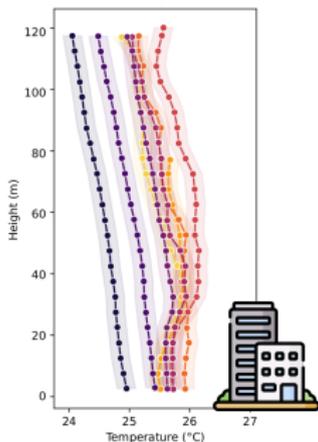


Profile start time (TU)

- 16:21
- 16:49
- 17:20
- 17:52
- 18:21
- 18:52
- 19:19
- 19:49

- 6/07/2023:
Urban environment impacts vertical profiles and cooling rate.

Georges Braque school



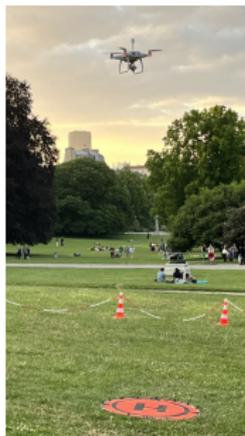
Profile start time (TU)

- 16:20
- 16:51
- 17:20
- 17:50
- 18:07
- 18:20
- 18:50
- 19:20
- 19:47

Nagel et al. [in prep]
Goret et al. [in prep]
Roberts et al. [in prep]

Urban vs Park cooling: vertical profiles

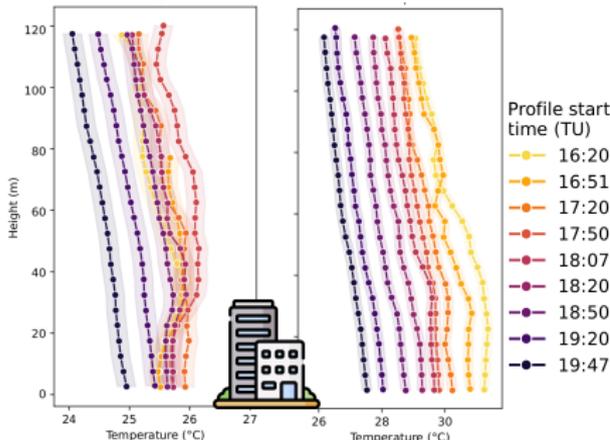
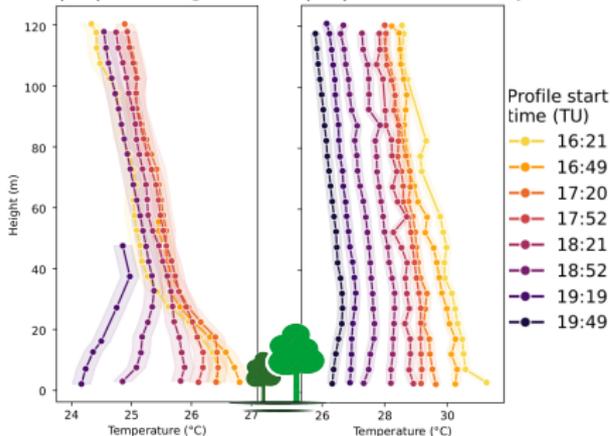
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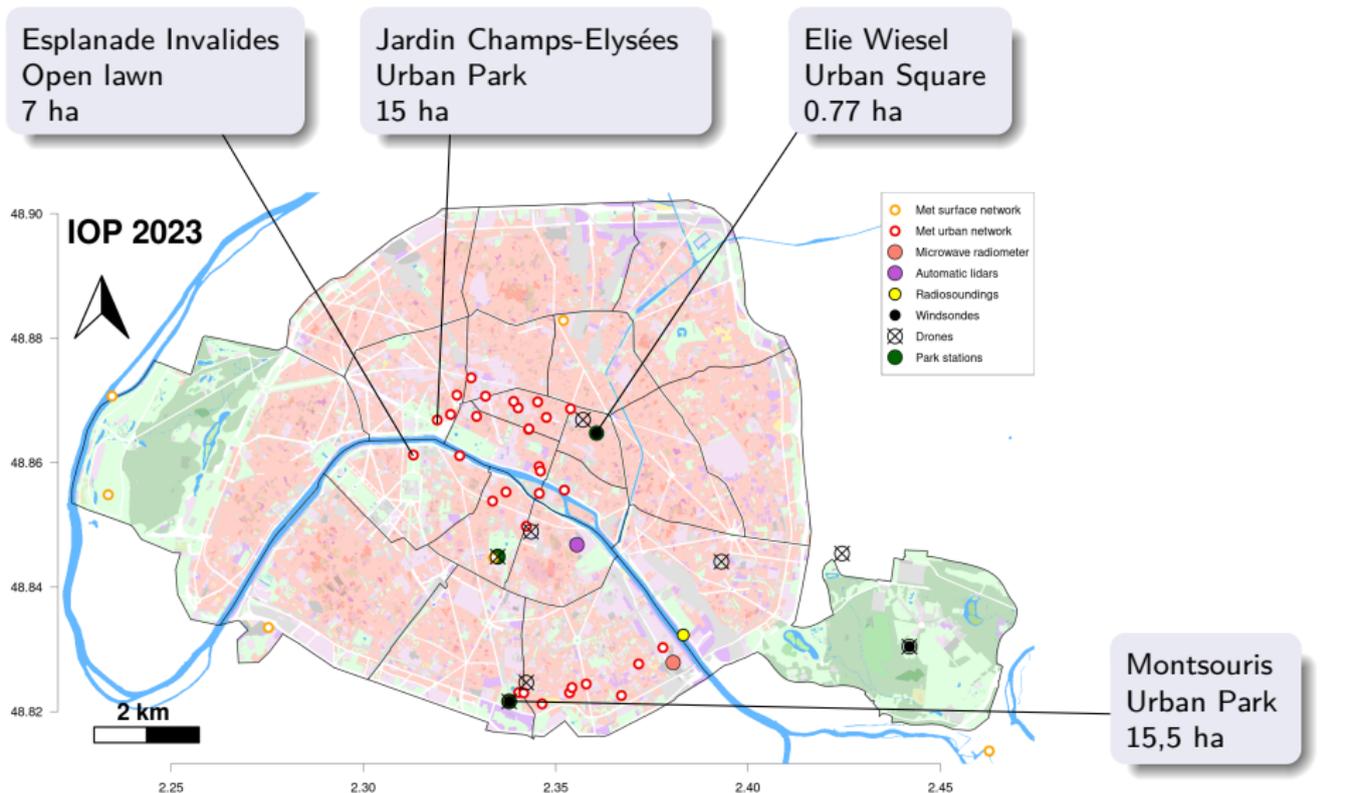
06/07/23 - Stagnant 11/07/23 - Intermediary



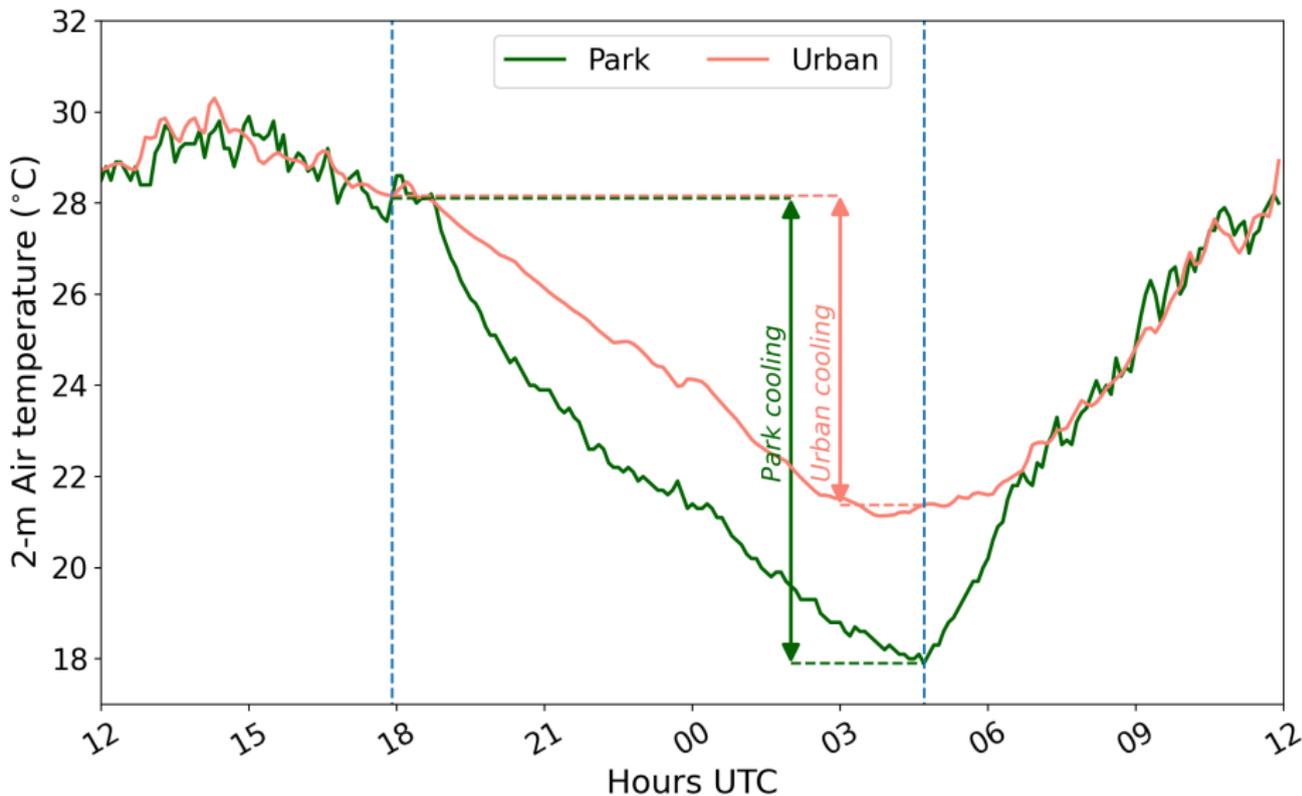
- 6/07/2023:
Urban environment impacts vertical profiles and cooling rate.
- 11/07/2023:
Similar cooling rate in park and urban environment
- Regional meteorology and turbulent mixing conditions play an important role upon cooling rate, at surface level but also in the urban boundary layer.

Nagel et al. [in prep]
Goret et al. [in prep]
Roberts et al. [in prep]

Urban park local cooling capacity

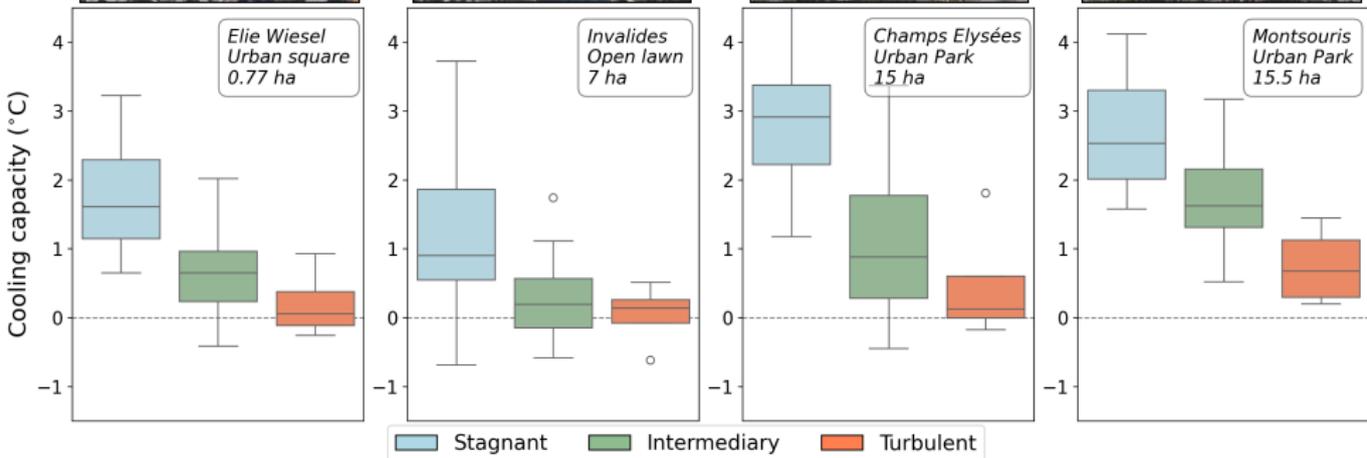


Urban park local cooling capacity:



- Cooling Capacity = Park cooling - Urban cooling
- Clear-sky days only from 15 June to 10 September 2023

Urban park local cooling capacity:



- Cooling capacity more important for stagnant regime.
- Lower cooling capacity for open lawns like Invalides.

- Cooling capacity significant for small urban square (Elie Wiesel).
- Local cooling capacity equivalent between Montsouris (close to outskirts) and Champs Elysées (downtown) for stagnant regime.

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Meso-NH

A high-resolution, mesoscale non-hydrostatic atmospheric model (Lac et al. [GMD, 2018])

- Driven by NWP AROME-France
- Coupled with the externalized surface platform SURFEXV9
- ISBA-MEB model for vegetation
- Multilayer version of Town Energy Balance (TEB - Schoetter et al. [GMD, 2020]) model to simulate urban elements
- Garden model for urban vegetation

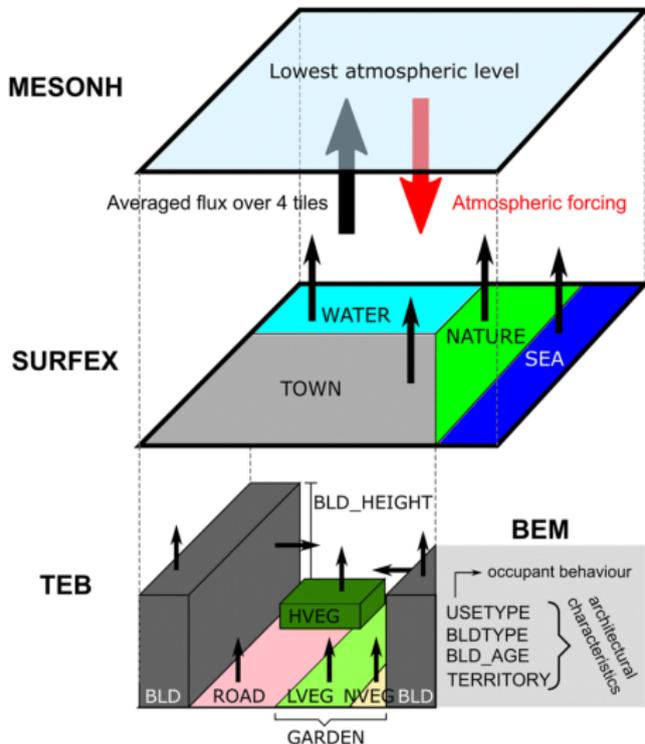
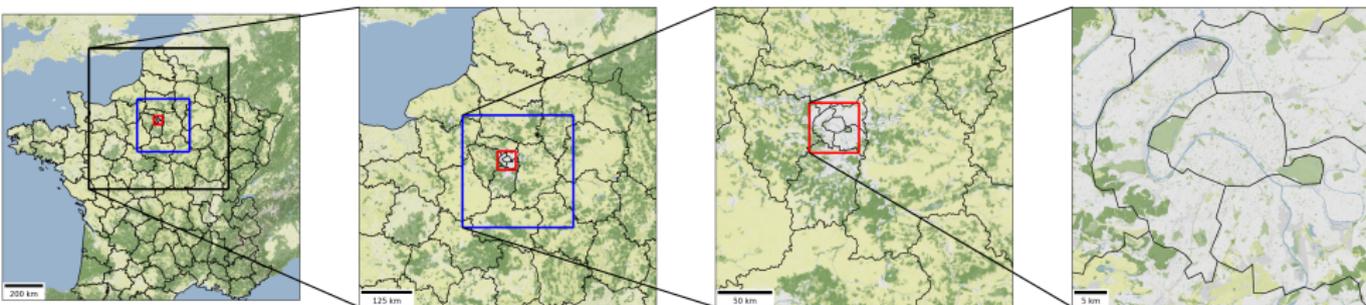


Figure from Kwok et al. [2020]

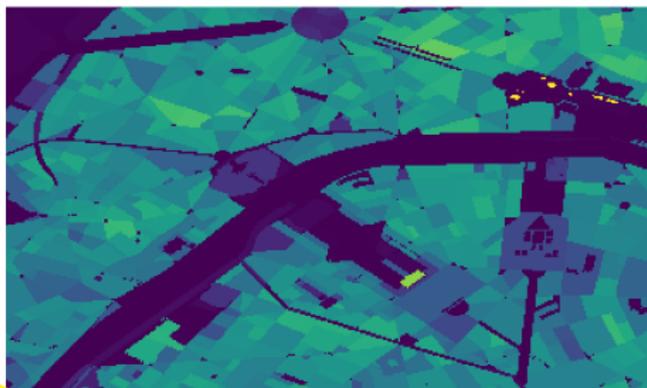
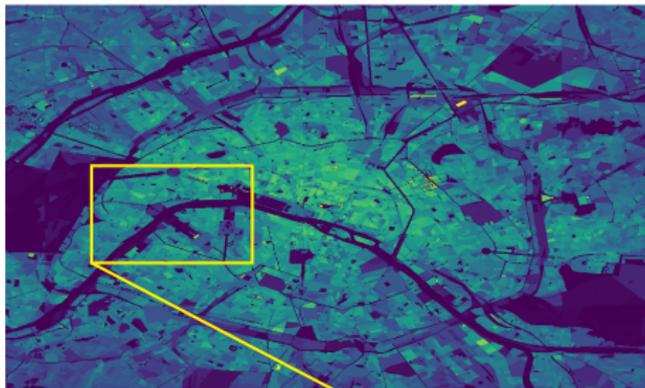
Meso-NH configuration

Region	Over AROME Grid	Over Paris Region	Over Paris city
Domain	D1	D2	D3
Area (km ²)	480×480	180×250	30×30
Resolution (m)	1200	300	100
Timestep (s)	10	2.5	0.8
Surface	EcoSG	OSM Data	OSM+Mapuce



High resolution surface database for urban areas

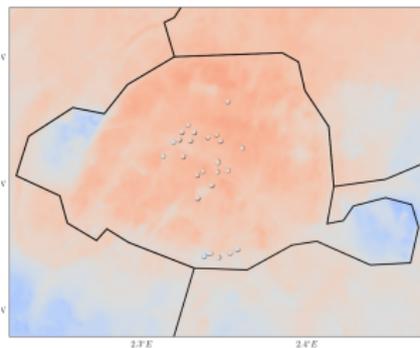
Obtained with the Geoclimate tool (Bocher et al. [2021]) from the Open Street Map database. Work in progress to make it available over Europe



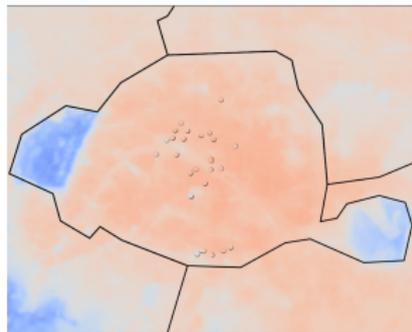
100m resolution surface
database

Nocturnal T_{min} patterns across stability regimes

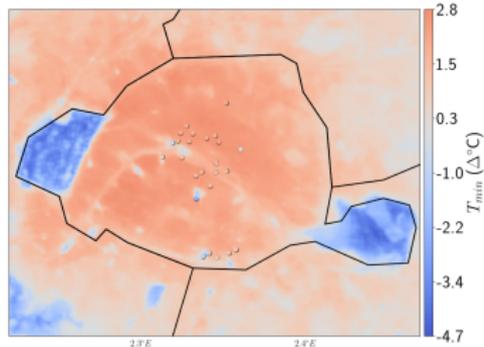
Turbulent



Intermediary



Stagnant



Difference from area mean in each regime (6.-23.7.2023):

- High-resolution models allow to see the intra-urban variability and the contrasting effect of weather conditions
- This requires fine resolution, processes parameterizations and databases

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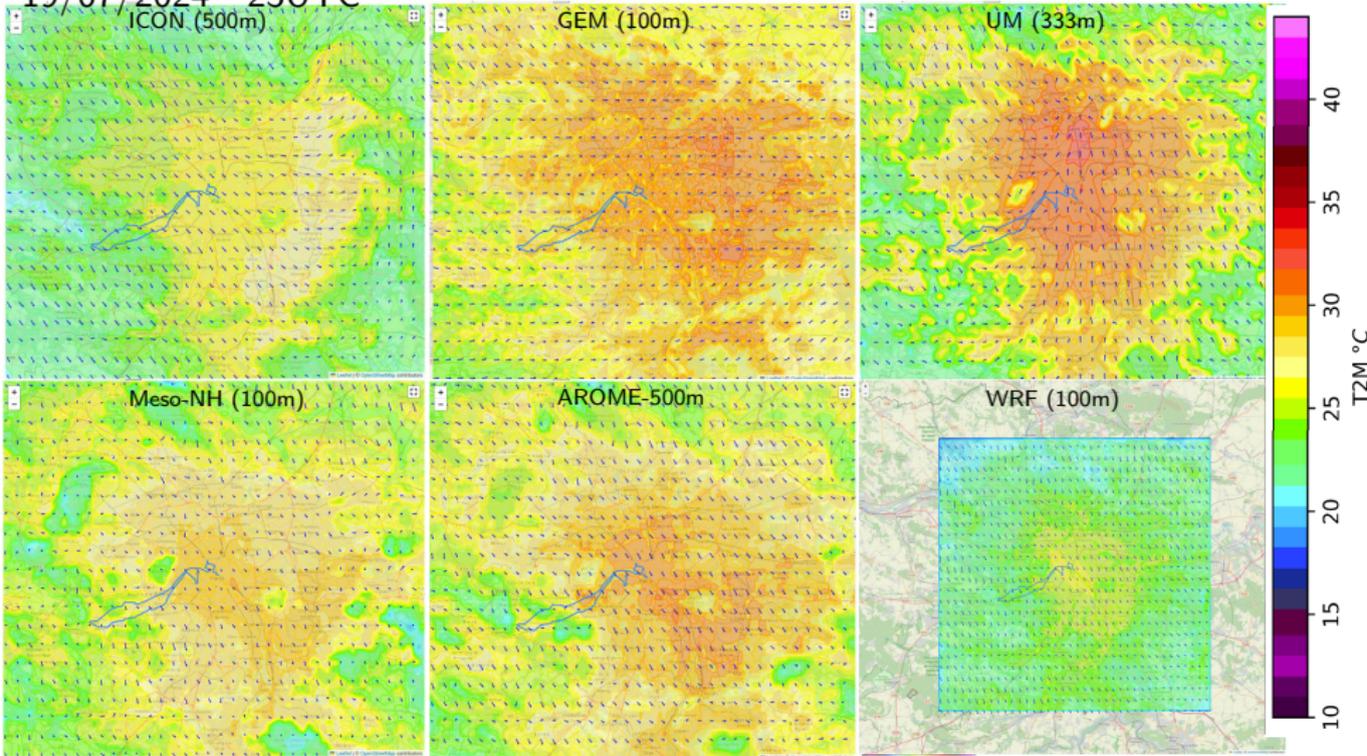
Intercomp: Research Demonstration Project Paris2024

Improvement of models & analysis of parameterizations Process :

- Model setups & discussion on diagnostics
- Forecasts every day during 2024 summer. All model outputs sent to CNRM
- Daily intercomparison and evaluation with observations

Centre	Model	Gridlength
Meteo-France (CNRM)	Meso-NH	100 m (Paris and suburbs) 300 m (Ile-de-France)
Meteo-France (CNRM)	AROME-500	500 m
Meteo-France	AROME-DBLE	1300 m
Met Office	UM	333 m
ECCC	GEM	100 m
NCAR	WRF	100 m
DWD	ICON	500 m

19/07/2024 - 23UTC

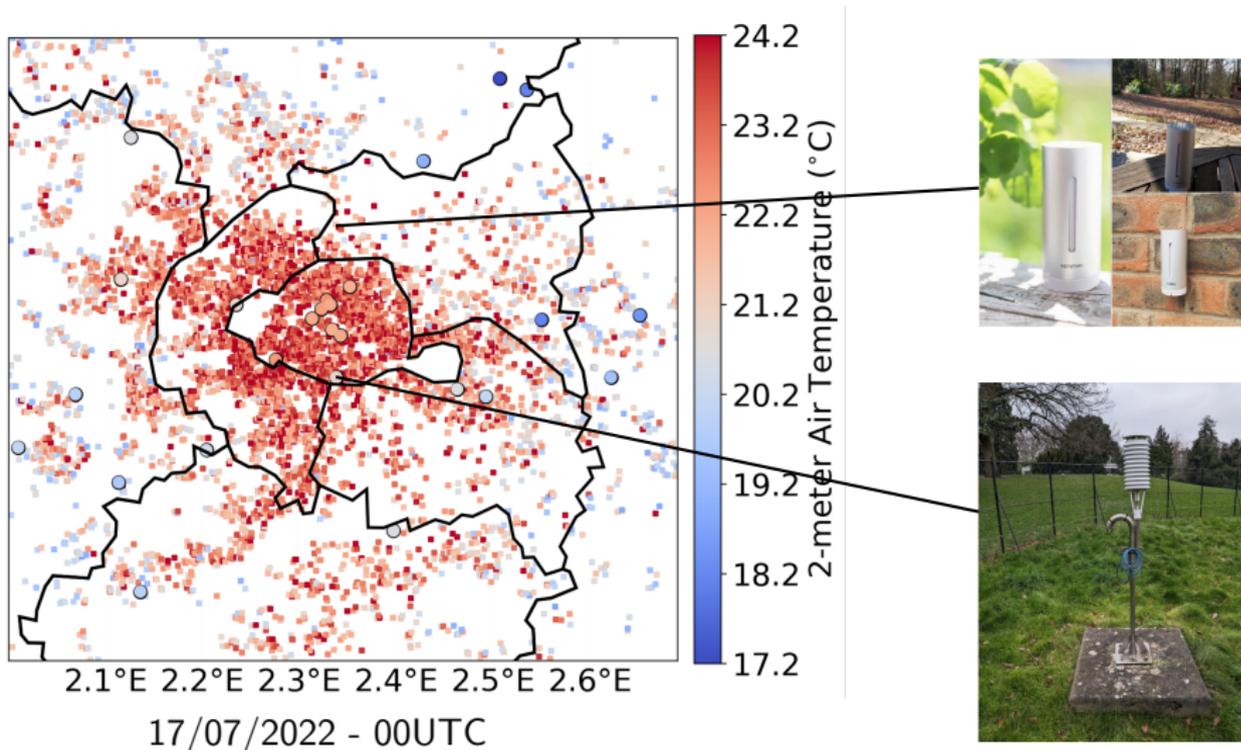


- All models produce an UHI, but of varying intensity and shape
- Some models have almost no wind, other wind of 10km/h, creating an urban plume
- The cool areas of the 2 big urban woods are often seen by all models
- But the infra-urban parks are usually only seen by 1 or 2 models

J. Wurtz (CNRM)

Crowd-sourced data

Netatmo citizen weather stations might also be used to complete the observation network and to assess model accuracy.

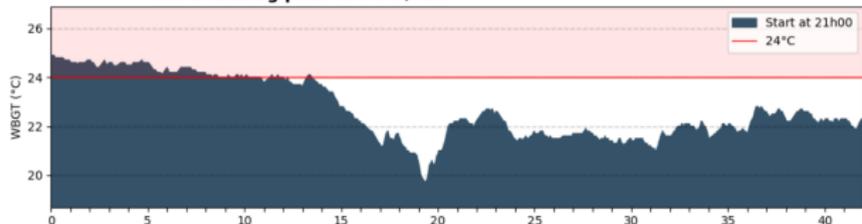


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Forecasting application: Marathon for All

VERY HOT DAY : 34-35°C

WBGT graph for the marathon course on a very hot summer day
(max air temp 34°C-35°C at around 4pm)
for a running pace of 6'00 / km

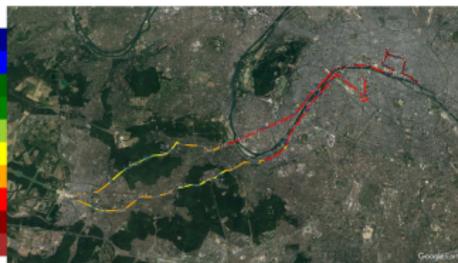
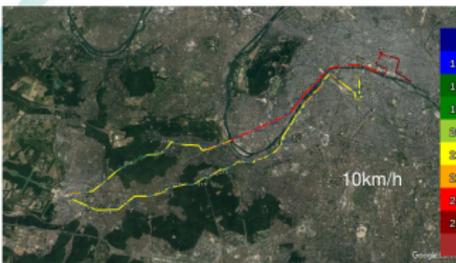


WBGT on the marathon course for a start at 21h
Very hot day 34°C-35°C max

24°

Study to quantify the thermal stress during the Marathon :

- Use of MesoNH hectometric simulations
- Selection of 4 days (from typical day to heatwave conditions)
- Analysis according to run speed of the participants
- WBGT (Wet Bulb Globe Temperature) is the sport regulations reference index

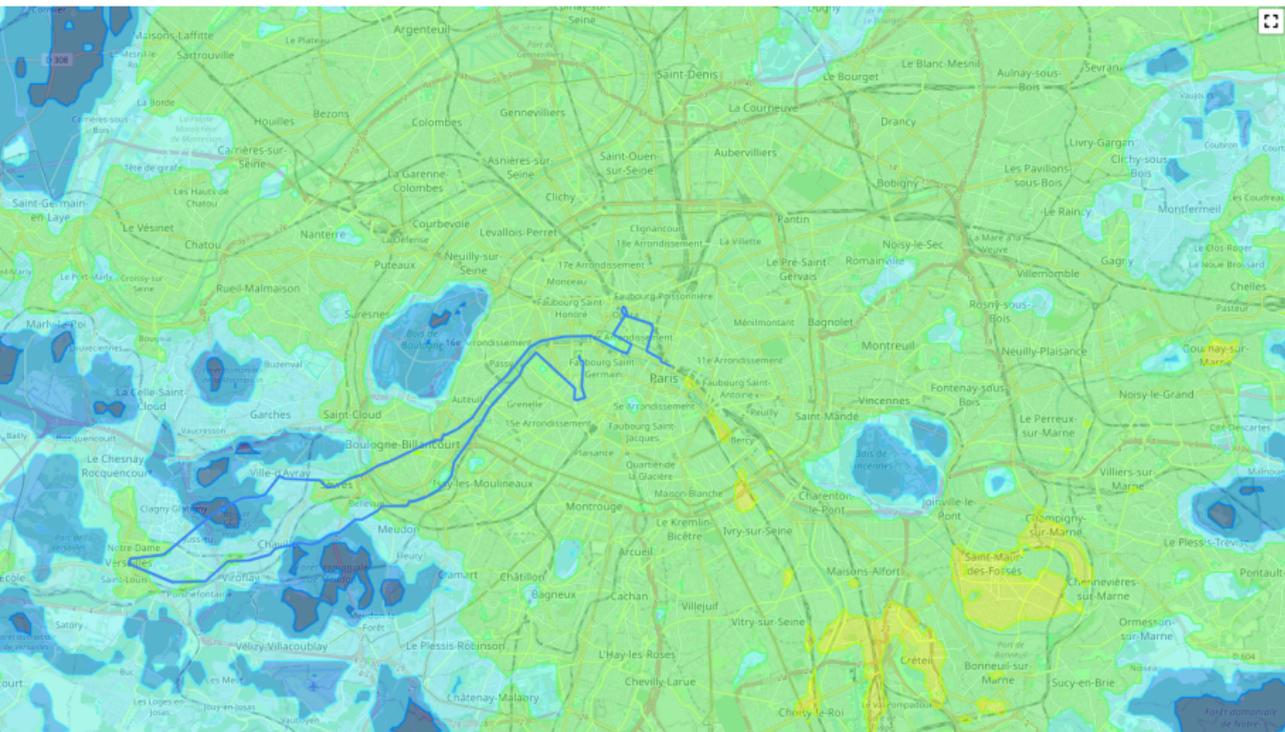


Pace at 10kph, the 16 first km are at risk (1h30 race) around WBGT 24°C. All the marathon is above 21°C with a slight increase while entering downtown.

Pace 18km/h, 45' race around 24°C, then decrease in around WBGT 22°C-23°C in the western half. Day at risk.

Forecasting application: Marathon for All

Meso-NH has also been used to perform dedicated forecast for the Marathon day (hot Tx $\approx 30^{\circ}\text{C}$ and clear day with ICU)



WBGT at 20UTC, the 10th of August 2024

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P. Abeillé (MF-Sport)

September 30, 2024

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Conclusions

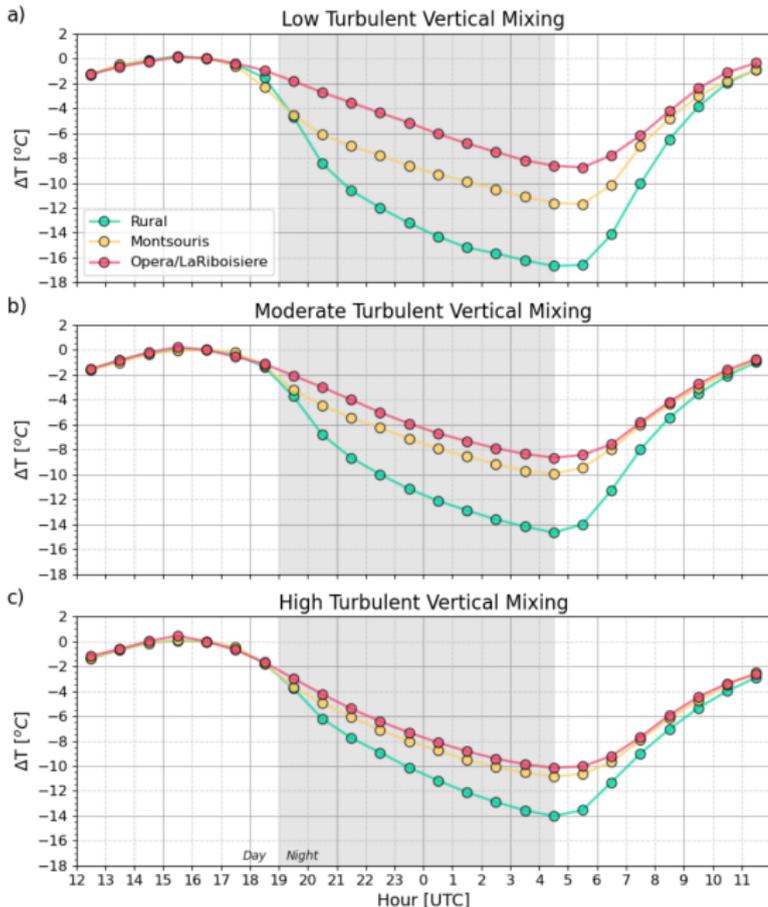
- PANAME multi-sensor and multi-scale approach provides an exceptional database for urban climate process studies and meteorological models evaluation.
- In stagnant regime, even small urban squares smaller than 1 ha have a cooling capacity significantly higher than build-up areas nearby.
- Hectometric models are required to fully capture the infra-urban variability.
- At Meteo-France, hectometric models (Meso-NH, Arome500) have been successfully used for realtime forecast during the Olympics and Paralympics. Very positive feedbacks from the forecasters

Ongoing work based on PANAME dataset

- Investigation of urban park cooling efficiency during summer in Paris with drones, sondes, and ground measurements.
- High-resolution modelling of park cooling efficiency during summertime in Paris
- NWP and hectometric Model Intercomparison for summer days.
- Population exposure to heat: what is the most appropriate urban units to assess the exposure?

2022 IOP: Impact of boundary layer stability on urban park cooling

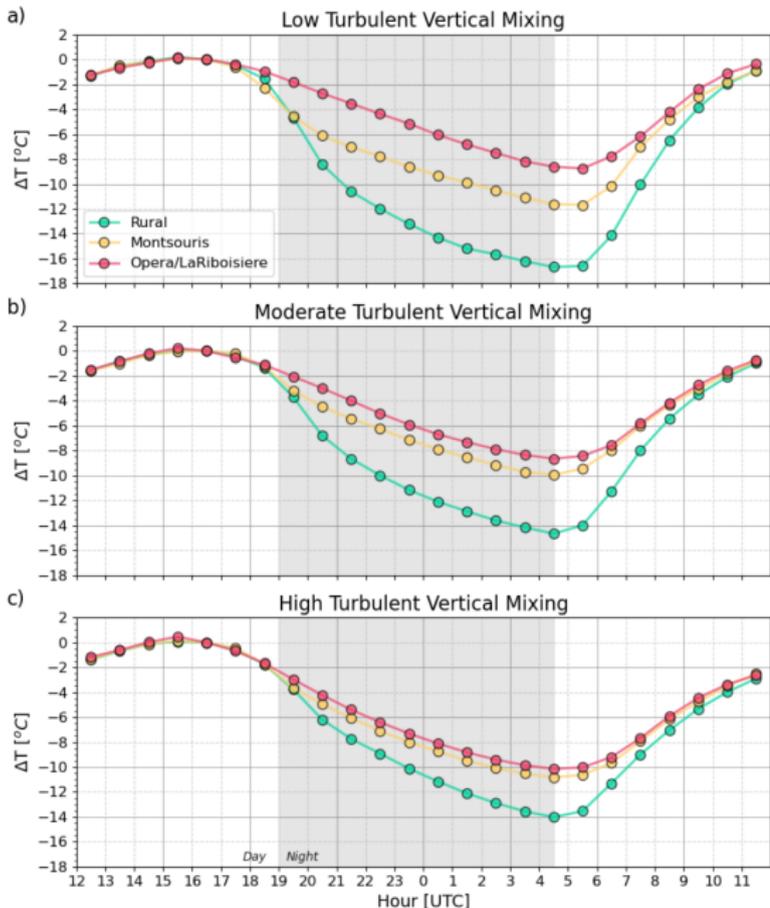
- Stagnant regime: Low turbulent vertical mixing (measured with Doppler Lidar), shallow UBL, decoupling between surface and elevated heights (300m). Mostly stable nocturnal UBL (stable RSL). Strongest evening cooling in rural settings and urban parks. Weakest cooling in built-up environment.



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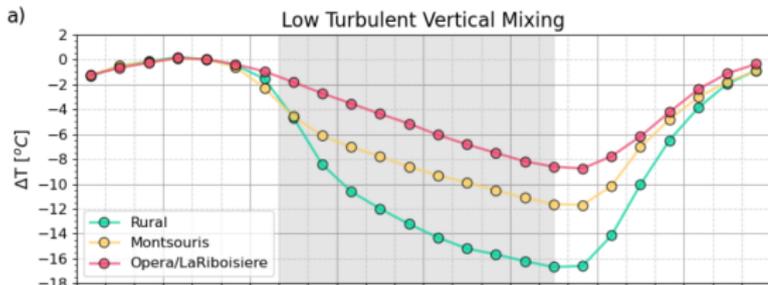
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- Intermediary regime: Moderate turbulent vertical mixing, coupling between surface and elevated heights. Neutral nocturnal UBL (stable RSL). Neighbourhood scale mixing: park cooling is slower. Urban cooling is higher as it benefits from vertical mixing with cooler air.

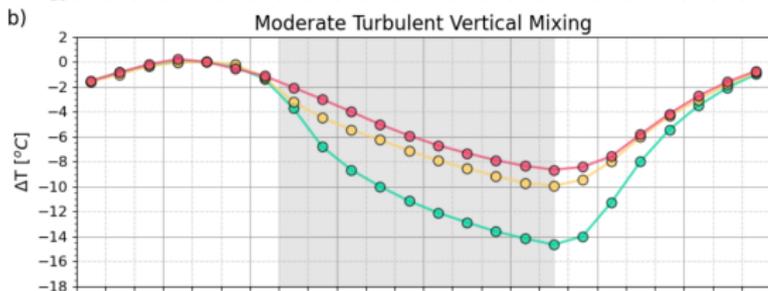


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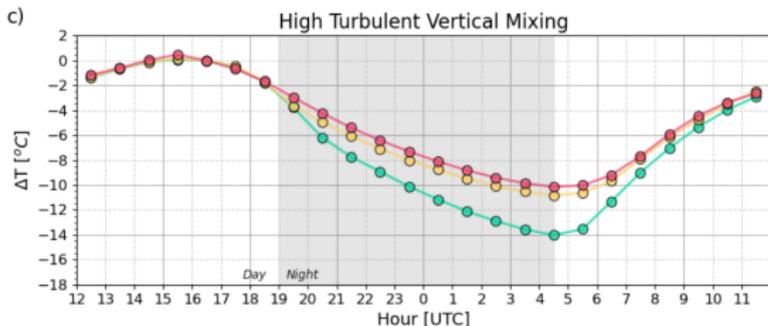
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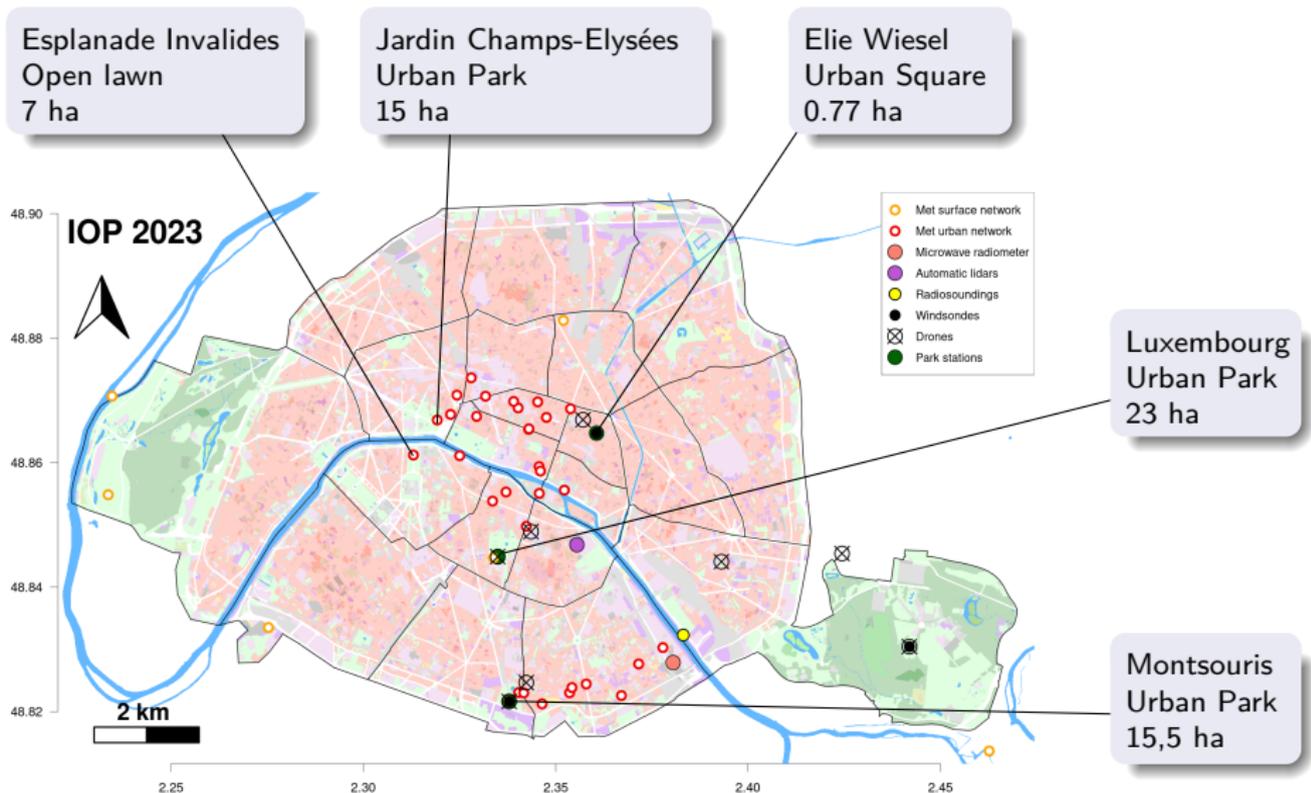
- Turbulent regime: High turbulent vertical mixing, deeper urban boundary layer (>600m). Neutral nocturnal UBL and RSL. District-to-city scale mixing. Evening cooling rates nearly identical in urban areas and parks.



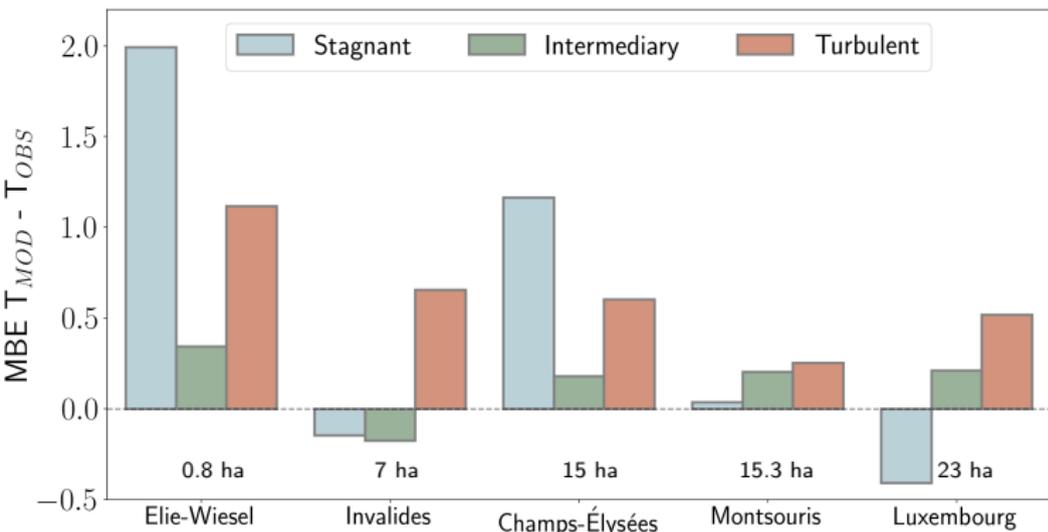
Surfex configuration

TILE	Model	Description	Reference
TEB	Multi-layer	Buildings interact directly with the first atmospheric layers of Meso-NH	Schoetter et al., 2020
	TEB-BEM	Building energy model calculates the energy budget of a representative building at the district scale	Bueno et al., 2012, Pigeon et al., 2014
	GARDEN	The in-canyon urban vegetation for ground vegetation, trees radiative and dynamic effects	Lemonsu et al., 2012, Redon et al., 2017, 2020
NATURE	ISBA	Evolution of the soil and the vegetation are computed by the Interaction Soil–Biosphere–Atmosphere land surface model	Noilhan et al., 1989
	DIF	Soil has 12 layers and parametrized with the explicit multilayer soil scheme	Decharme et al., 2011
	ISBA-A-gs	CO ₂ fluxes	Calvet et al., 1998, Gibelin et al., 2006
	AST	The drought response is Avoiding or Tolerant	Calvet et al., 2000, 2004
	MEB	Multi-Energy Budget parametrization, the vegetation canopy is separated from the ground	Boone et al., 2017

Model Evaluation



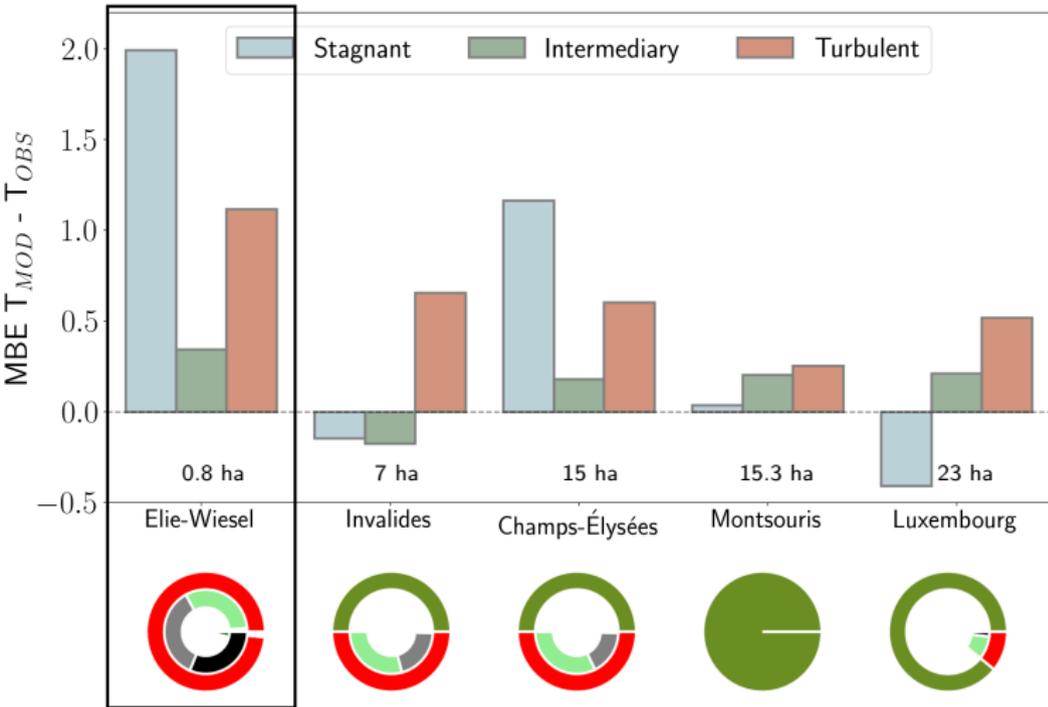
Model evaluation - Park stations (MBE)



Evaluation performed on the closest model grid to station



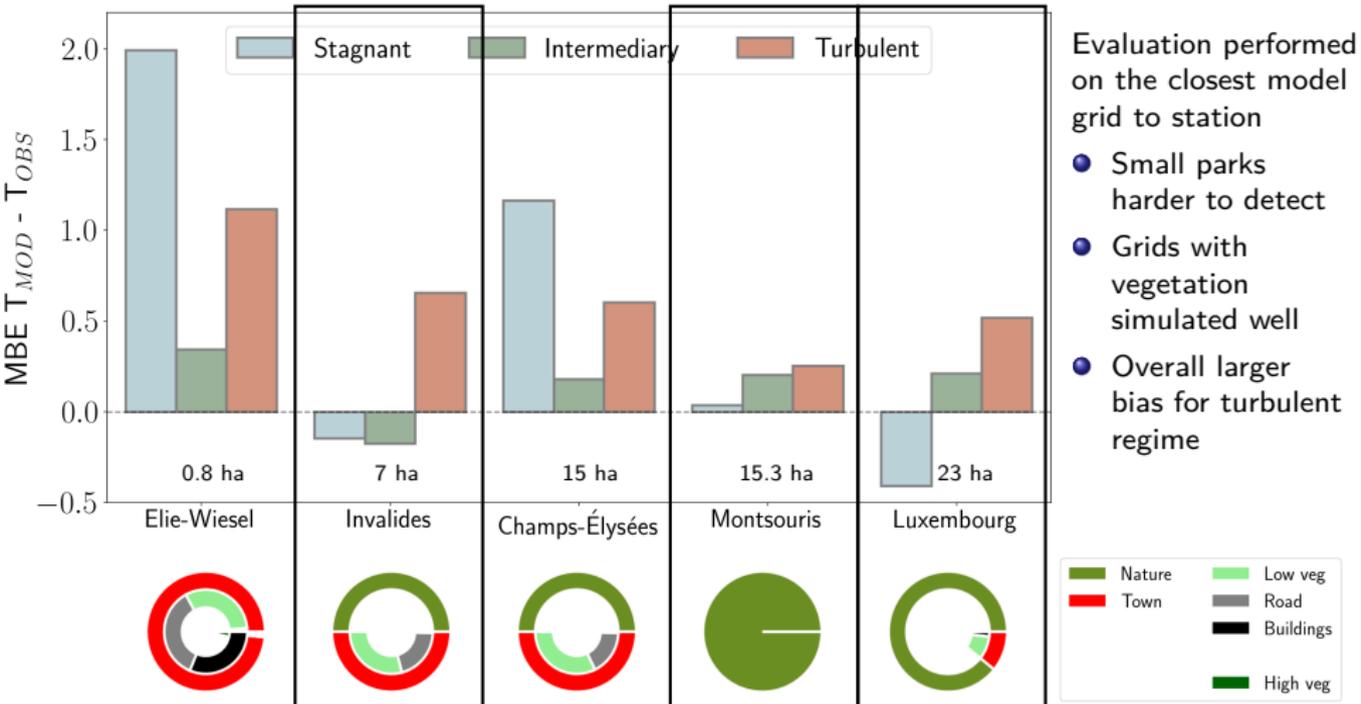
Model evaluation - Park stations (MBE)



Evaluation performed on the closest model grid to station

- Small parks harder to detect

Model evaluation - Park stations (MBE)



Allows to use the model in order to calculate the green areas nocturnal cooling efficiency for the entire city (work in progress)