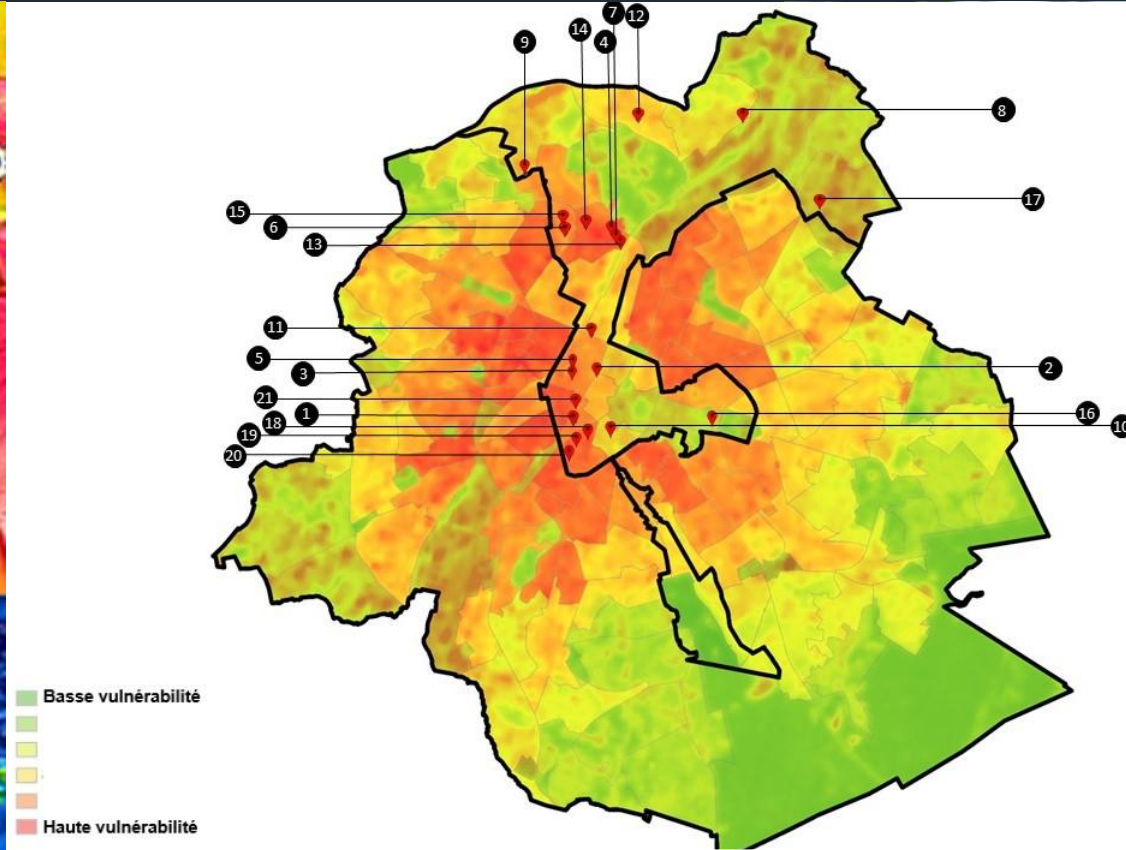


Multimodal Urban Heat Island Detection and Forecasting for Sustainable Cooling in Cities



Prof. Dr. Shady Attia
Sustainable Building Design Lab, UEE,
School of Engineering, University of Liège, Belgium
shady.attia@uliege.be

[in /in/shady-attia-14352a7](https://www.linkedin.com/in/shady-attia-14352a7) www.sbd.uliege.be
www.shadyattia.org [R^g](https://www.researchgate.net/profile/Shady-Attia)
[YouTube](https://www.youtube.com/channel/UC...) [bilibili](https://www.bilibili.com/channel/UC...)

1/30

Acknowledgment



CHONGQING
UNIVERSITY



Chongqing University 31.05.2025

- Project Members: Hicham ARRAR, Elhadi MATALLAH

IEA EBC - Annex 97 - Sustainable Cooling in Cities



International
Energy Agency

Special attention is given to the objectives of the newly launched IEA EBC Annex on Sustainable Cooling in Cities and its role in supporting evidence-based UHI mitigation.

Topic
Climate Change and Environmental Sustainability, 4th Edition

Topic Editors
Prof. Dr. Baojie He
Prof. Dr. Ali Cheshmehzangi
Prof. Dr. Shady Attia
Dr. Zhengxuan Liu

Deadline
Abstract Submission:
1 May 2025
Manuscript Submission:
1 July 2025

Participating Journals
Buildings, Forests, Land, Remote Sensing, Smart Cities, Sustainability, Atmosphere



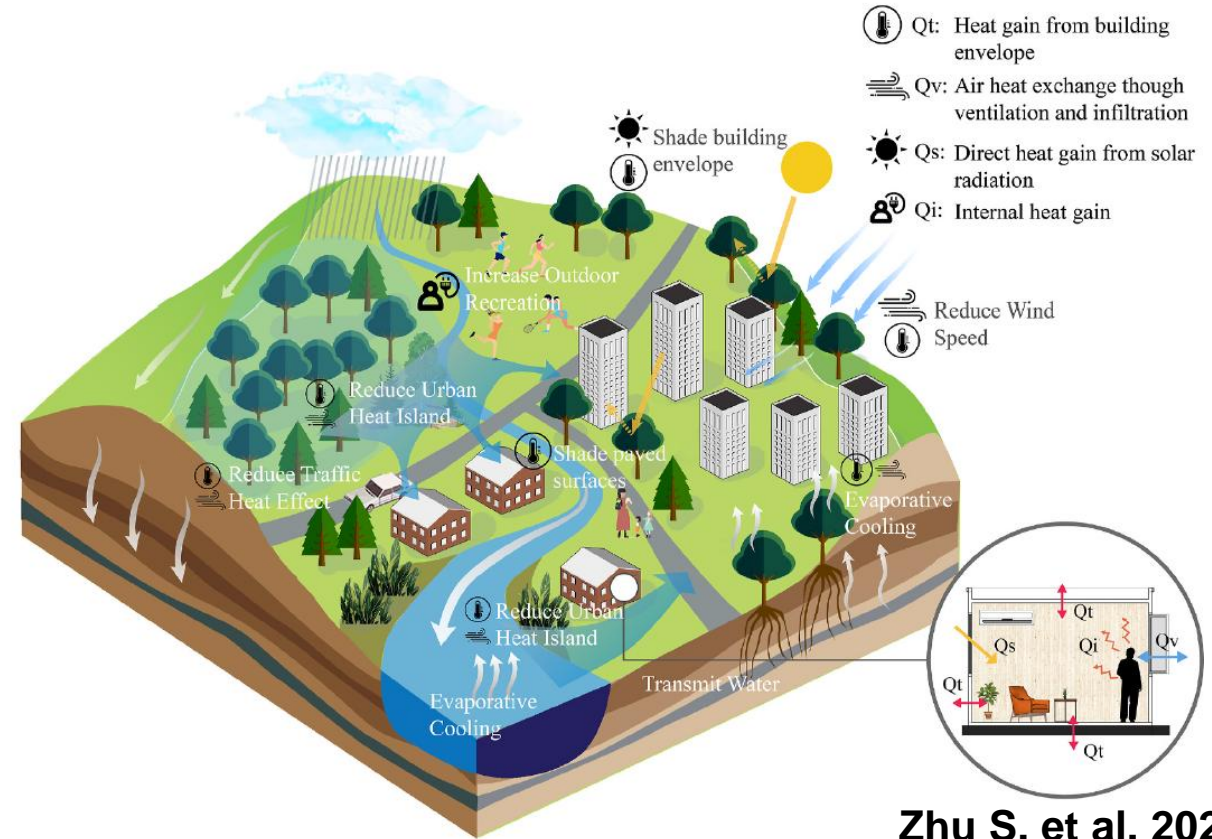
Urban Heat Island Effect Phenomenon



Urban heat island effect 城市热

□ Enlarge the outdoor cooling period

Roofs and pavements cover about 60 percent of urban surfaces and absorb more than 80 percent the sunlight that contacts them. This energy is converted to heat, which results in hotter, more polluted cities, and higher energy costs.



Why are Europeans vulnerable to heat waves?

欧洲人为什么容易受到热浪的侵袭？

1. High Humidity

2. Low Wind Speed

3. Longer Days Latitude above 30

4. Buildings and Cities Unfit for the Climate

5. Low Heat Shock Gene/Protein* 5 & 6 correlated

6. Light Skin Colour* (Melanin Biosynthesis) UV

7. Dry Soils



1. Satellite Remote Sensing

卫星遥感



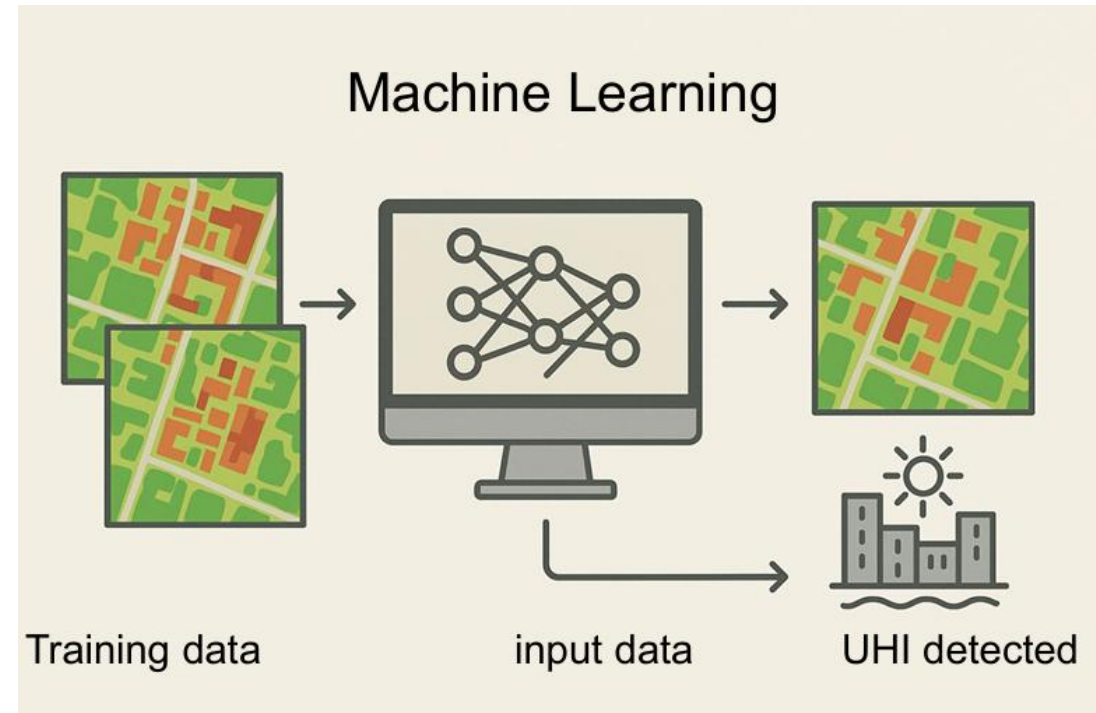
Detection of UHI via image analysis

Main Types of Machine Learning

Supervised Learning: The algorithm is trained on labeled data (e.g., images tagged as "cat" or "dog") so it can learn to make predictions or classifications.

Unsupervised Learning: The algorithm analyzes unlabeled data to discover hidden patterns or groupings (e.g., customer segments).

Reinforcement Learning: The model learns by trial and error, receiving feedback through rewards or penalties (commonly used in robotics or game playing).



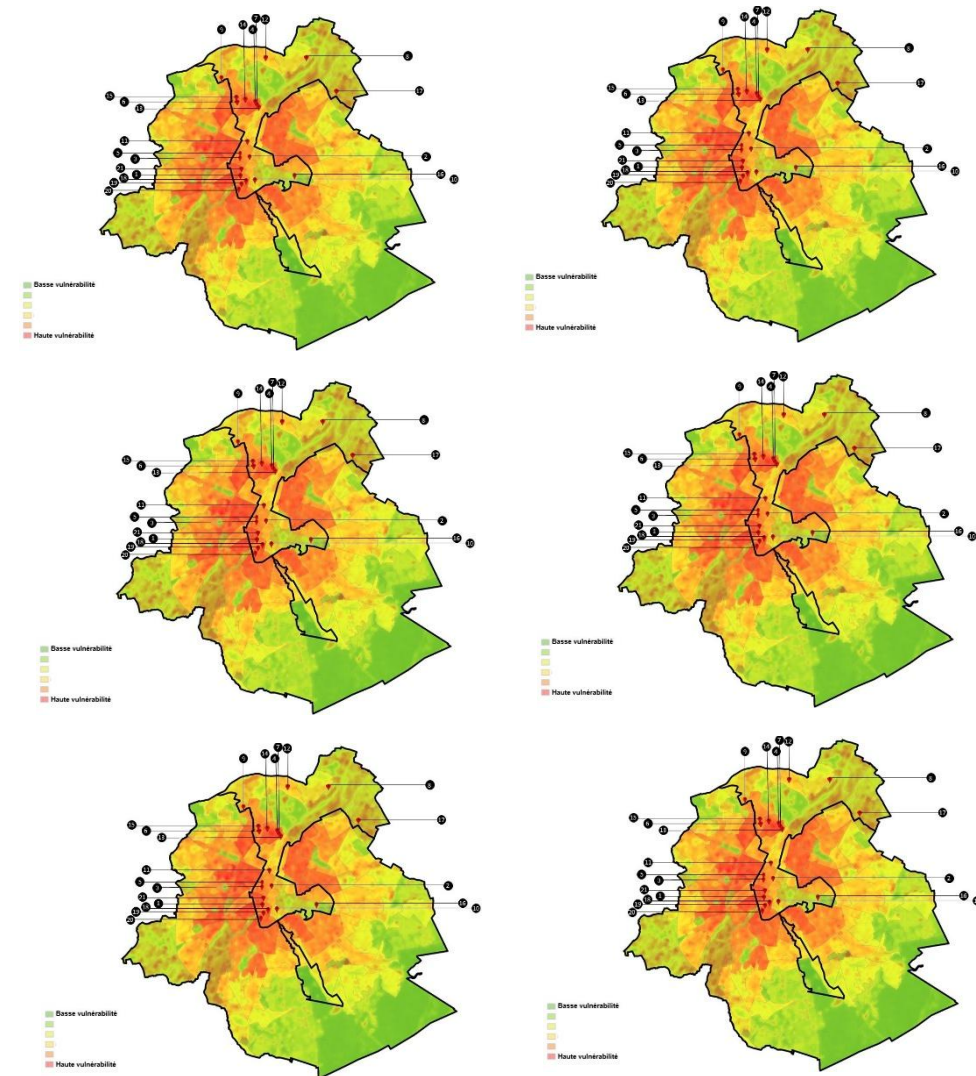
UHI Forecasting Brussels, Belgium

Input Data:

- Land use/land cover data (vegetation, impervious surface, materials etc.)
- LST data: Landsat 8 & KOPMSAT

Training of UHI categories: Impact of vegetation, surface features on UHI effects.

1. Urban density
2. Brightness
3. Atmospheric pressure
4. Vegetation index
5. Surface emissivity
6. Daily Excess Mortality



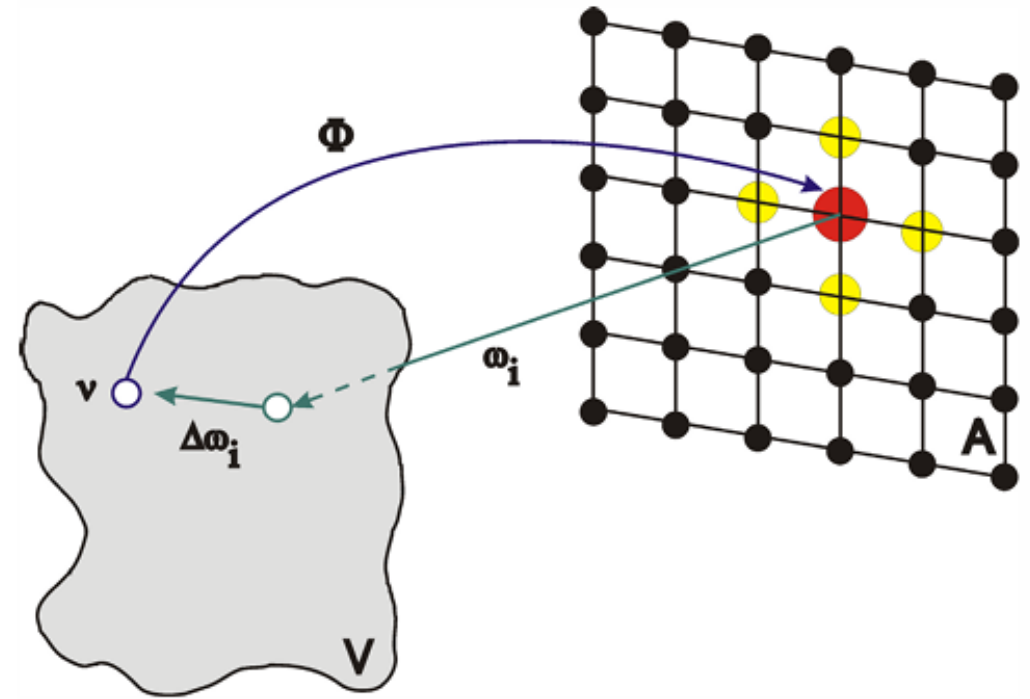
Learned Lessons

-Machine learning concepts can only learn from examples: newly emerging patterns cannot be discovered.

-Operator needs experience and routine

-We recommend **Gradient Boosted Trees** (e.g., XGBoost) or **Random Forest Regression** for handling non-linear effects well & explains feature importance (e.g., how much vegetation reduces heat).

These models showed us that vegetation and emissivity are key variables in predicting UHI hotspots across time.



- There is a need for statistical method that:
- Eliminates redundant information
 - Avoid topological distortions
 - Estimate embedding dimension (degrees of freedom)
 - Find suitable classifier

2. Drone Photogrammetry

无人机摄影测量

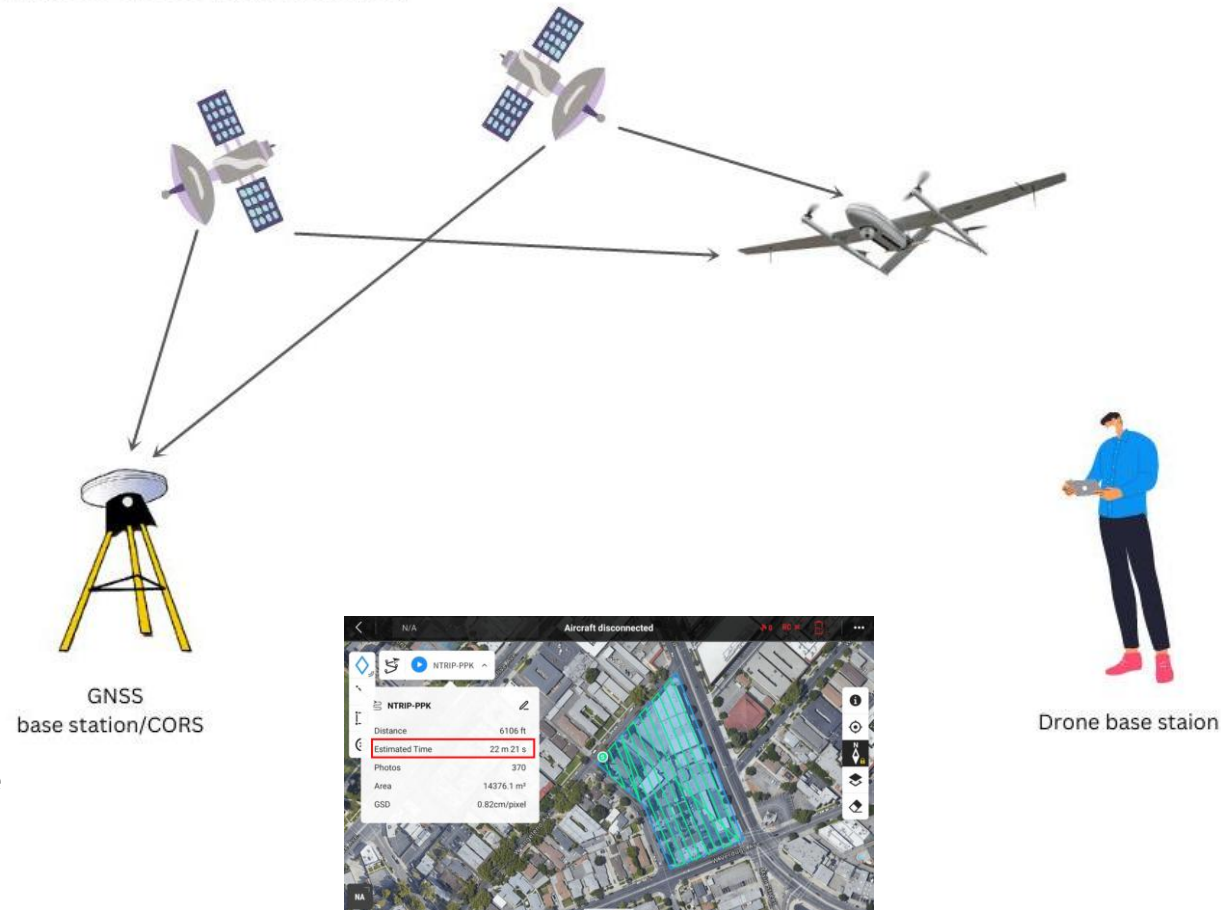


PPK image correction

Precise positioning technology does not perform GPS position correction in real time during the drone flight, but at the end of the flight.

- During drone missions, real-time GPS correction (RTK) was not used due to environmental or logistical constraints.
- Instead, Post-Processing Kinematic (PPK) correction was applied after the flight to improve spatial accuracy of captured imagery.
- **High positional accuracy is essential for:**
 - Aligning thermal data with urban infrastructure,
 - Avoiding spatial drift in dense environments,
 - Ensuring reliable UHI zone detection and longitudinal comparison.
- In our 2022 Brussels campaign, PPK improved the geo-referencing of both RGB and thermal orthomosaics, enabling robust integration into GIS and climate models.

PPK (Post-Processing Kinematics)



Capturing Urban Heat Signatures via Drone Photogrammetry

1. Utilized DJI Zenmuse H20T + Matrice 210 RTK for thermal and RGB data acquisition.
2. Enabled aerial thermal imaging and photogrammetric mapping over Brussels.
3. Post-processed imagery corrected using PPK methods for geo-referenced accuracy.
4. Data supports surface temperature mapping at street and rooftop scale.



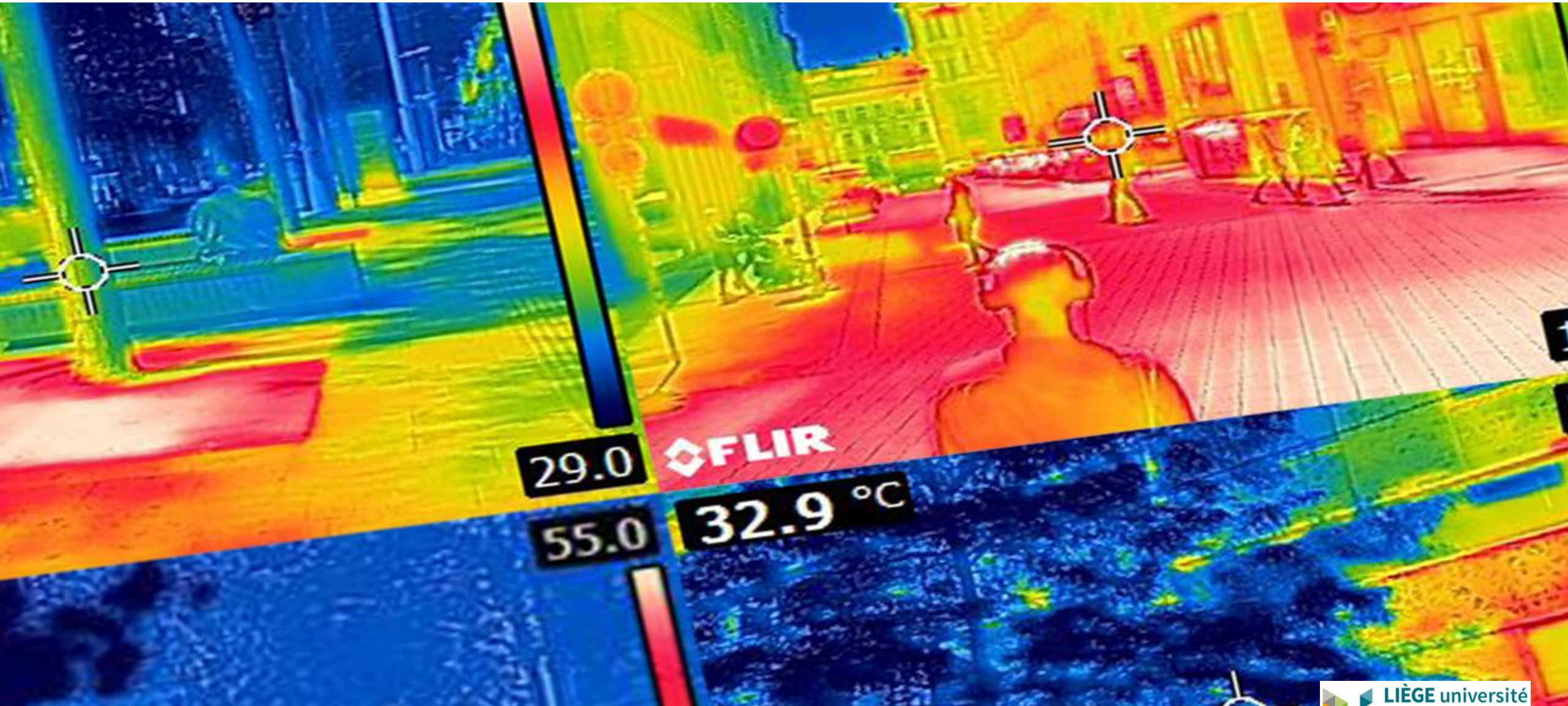
DJI Matrice 210 RTK



DJI Zenmuse H20T

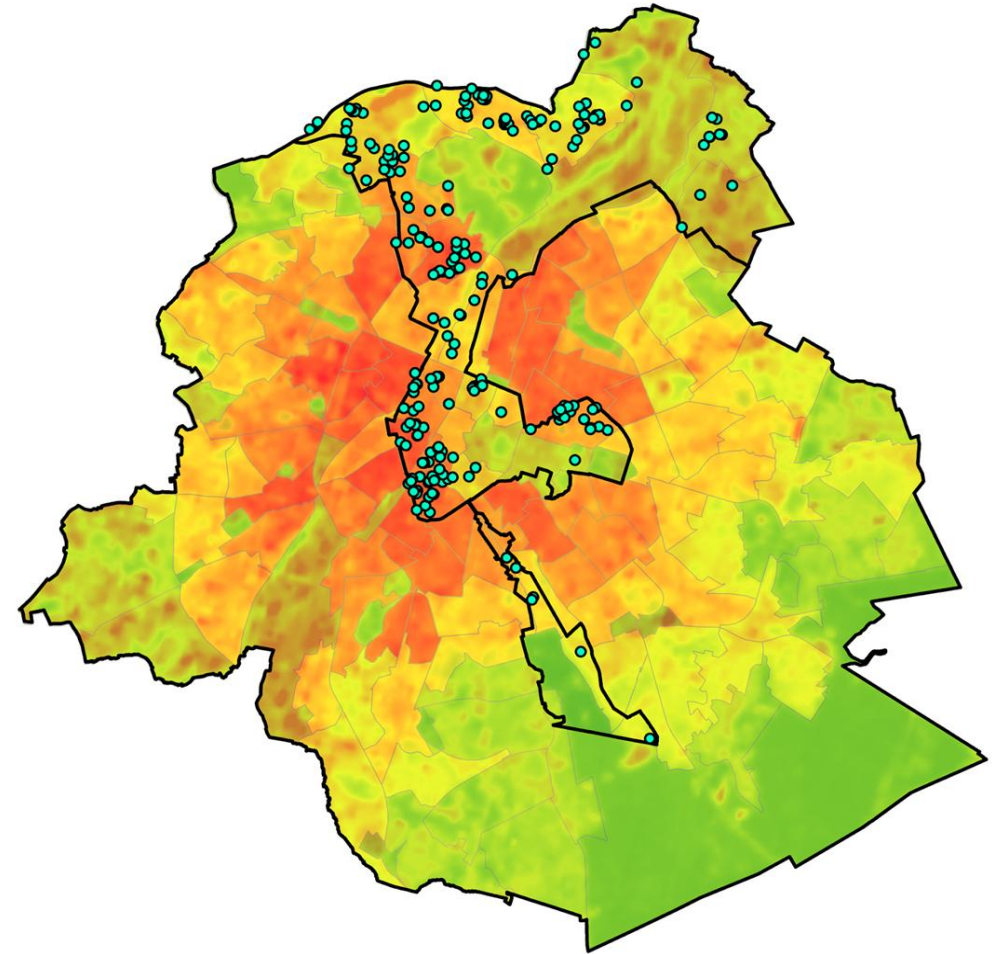
Supports detection of thermal anomalies and urban microclimate gradients.

Brussels: Drone Summer 2022



Workflow, processing speed, data outputs

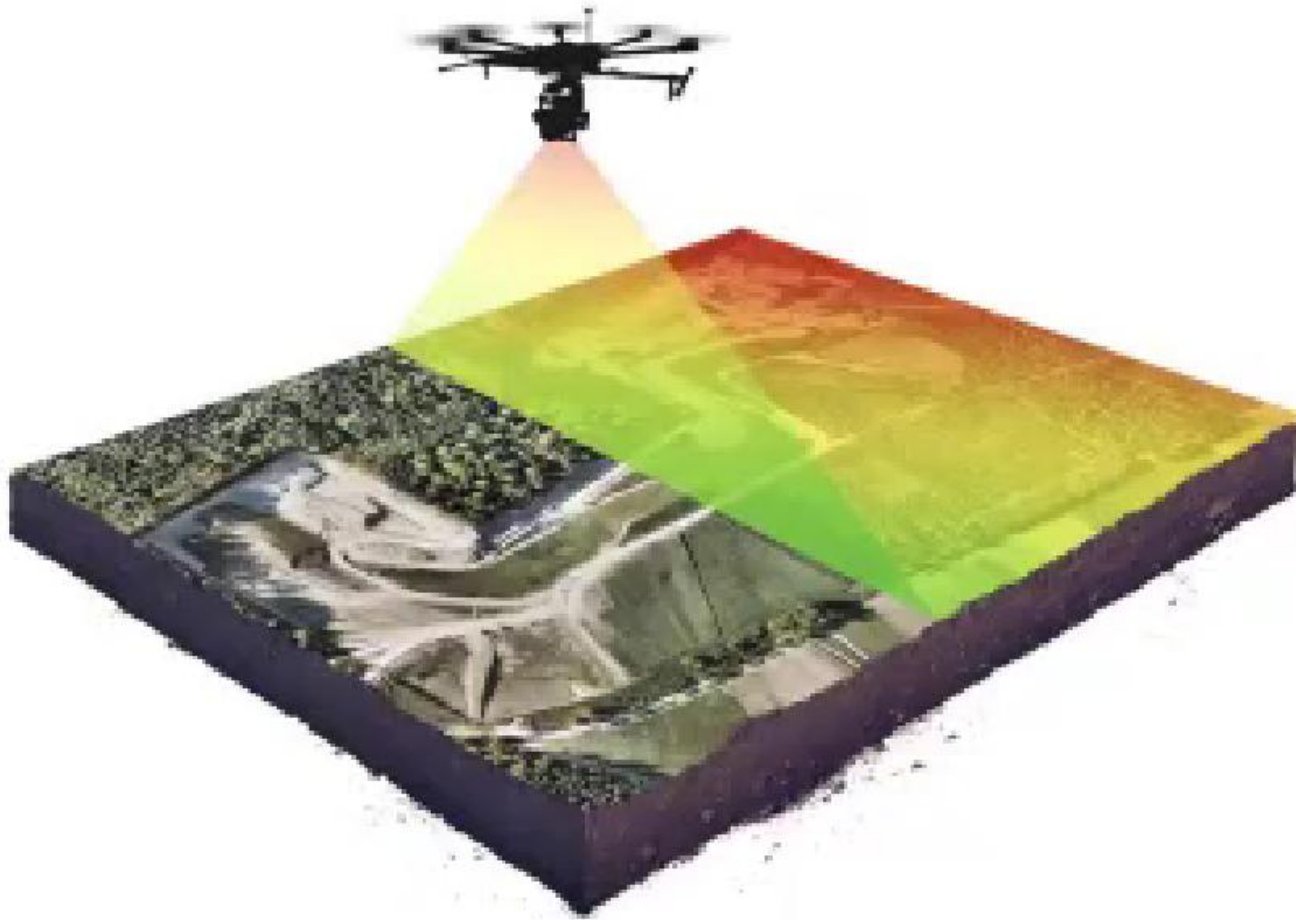
- **Well developed processing workflow**
 - + PPK correction (image geotagging)
 - + Photogrammetric processing
 - + Analytics / added value / etc.
- **Computationally expensive but not labor intensive**
 - + Hours to days for full-resolution
 - + Less than an hour if only a sparse but accurate point cloud is needed
- Rich photorealistic data outputs. Dense point cloud, DSM, DTM, Orthomosaic



3. LIDAR 激光雷达



Drone LIDAR – light detection



- **Laser + IMU + GNSS/PPK**
- **Direct geo-referencing**
- Heavy manned LIDAR vs
- **Lightweights drone LIDAR vs**
- Cheap drone LIDAR

- Multicopter vs **fixed-wing/VTOL**

Drone LIDAR – light detection



DJI Matrice 210 RTK

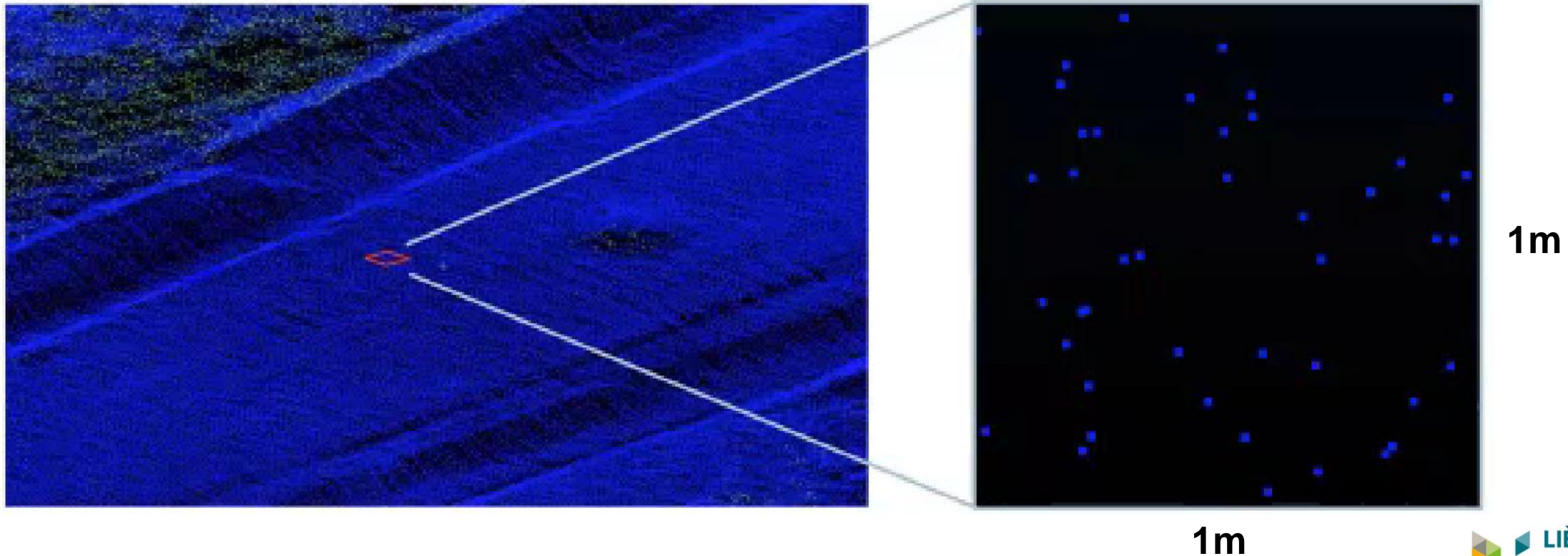
DJI Zenmuse L2 RGB/LiDAR



DJI Zenmuse H20T

Drone LIDAR – light detection

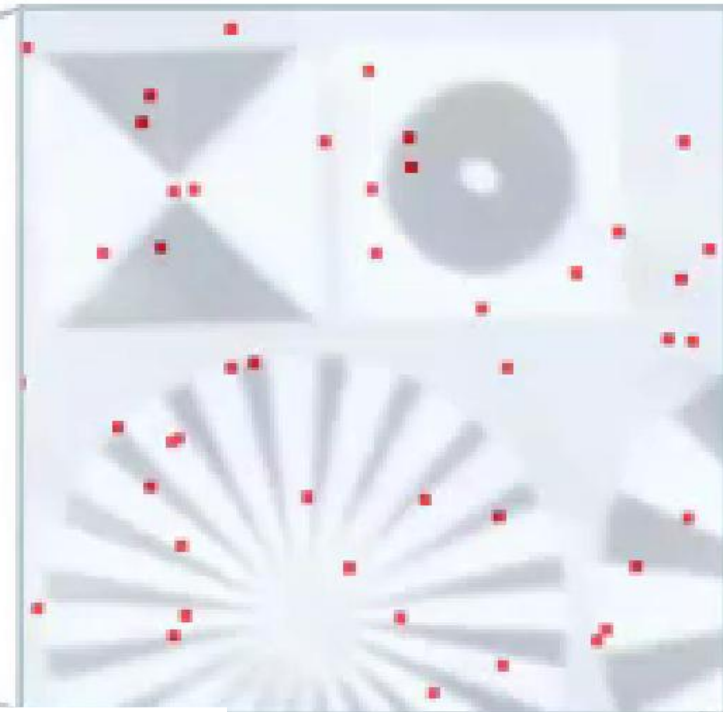
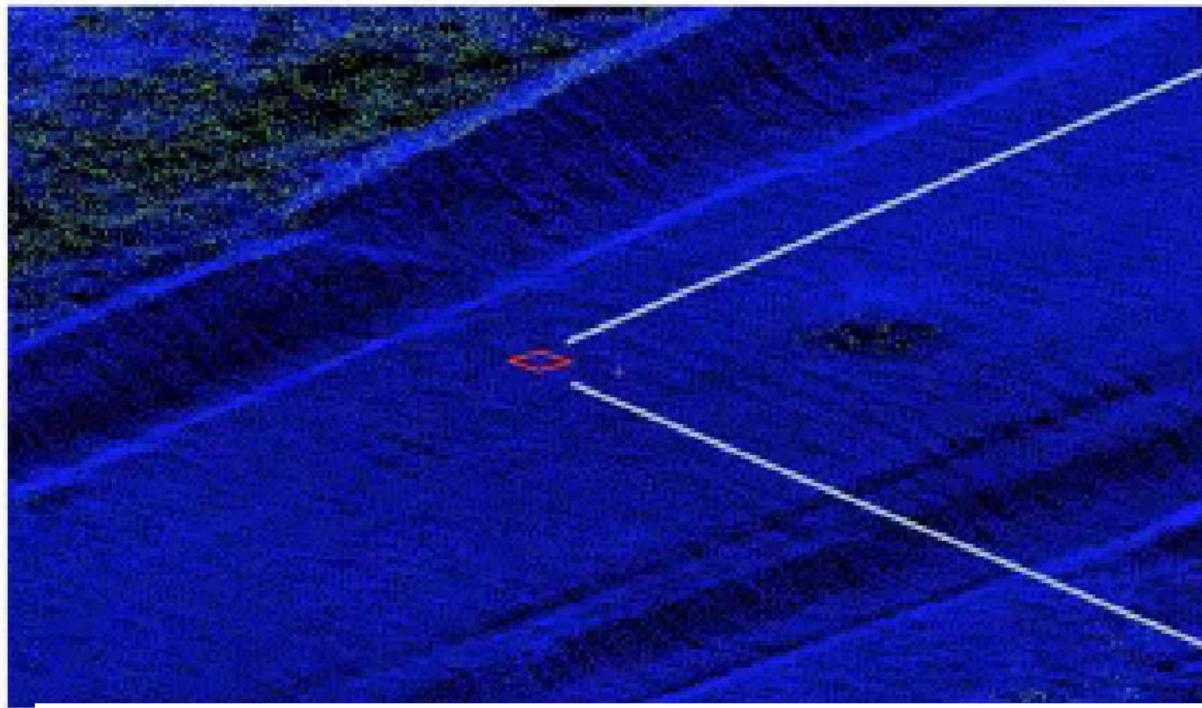
- **Resolution / point density (fixed-wing)**
- Typically 50 – 200 pts/m² not uniformly distributed
- **Absolute accuracy**
- Typically horizontal accuracy: ~10 cm
- Typical vertical accuracy: ~ 5 cm



Drone LIDAR – light detection

- **Resolution / point density (fixed-wing)**
- Typically 50 – 200 pts/m² not uniformly distributed

- **Absolute accuracy**
- Typically horizontal accuracy: ~10 cm
- Typical vertical accuracy: ~ 5 cm



1m

1m

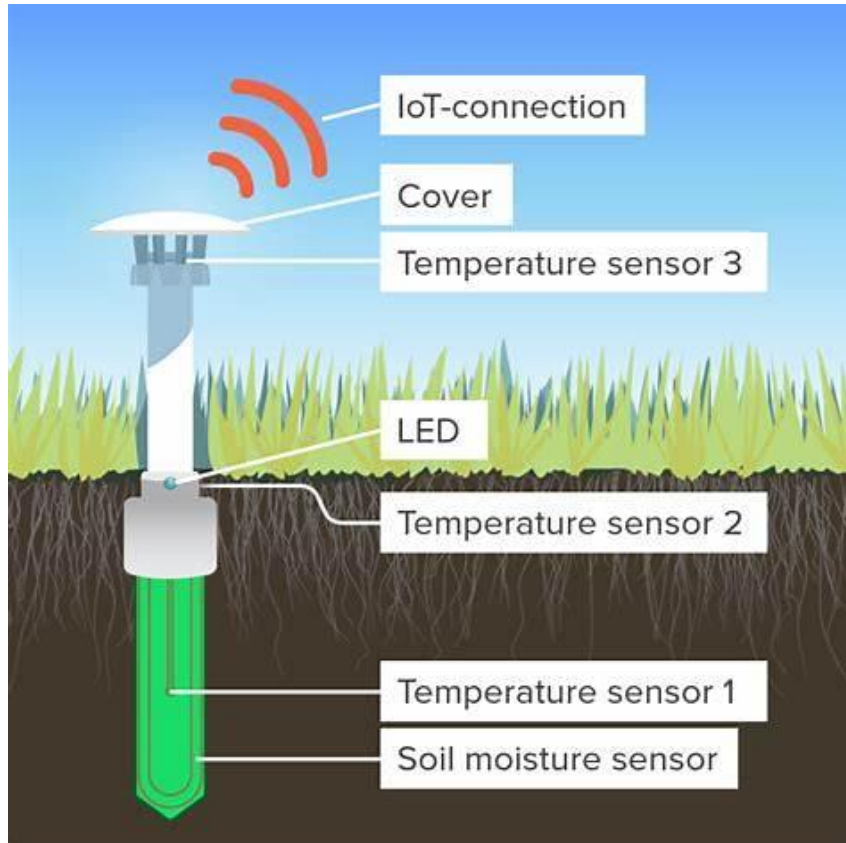
4. Volumetric water content (VWC) Monitoring

土壤体积含水量监测



Volumetric water content (VWC)

- **Capacitance-based sensors TERSOS 12**
- Sensors connected to data loggers equipped with LoRa WAN technology. wireless transmission of data every 15 minutes.



Citizen-generated data from 5,000+ soil sensors in gardens and parks.

VWC & soil temperature 土壤体积含水量

- **Absolute accuracy:** $\pm 3\%$ in mineral soils; improved to $\pm 1-2\%$ with soil-specific calibration.



Case Study

案例研究



Brussels Case Study 布鲁塞尔案例研究



BRUSSELS · FULL CITY

WS_02_Heliport

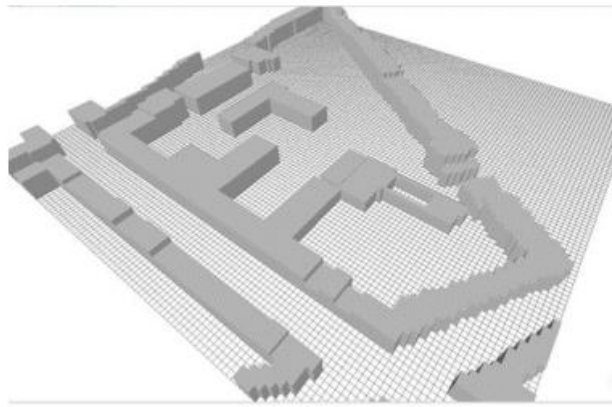


Brussels Case Study

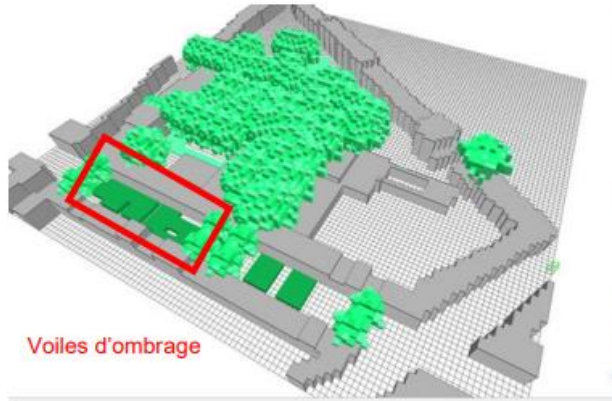
布鲁塞尔案例研究

Rafraîchissement attendu : **-10°C P.E.T.** (zone 3 - Athénée et Rue Marie-Christine)

Simulation 19 juillet 2022 à 16h (température de l'air : 40°C) :



55°C



Voiles d'ombrage



45°C (- 10°C P.E.T.)

PET



Conclusion

结论



Multimodal Urban Heat Island Detection and Forecasting for Sustainable Cooling in Cities

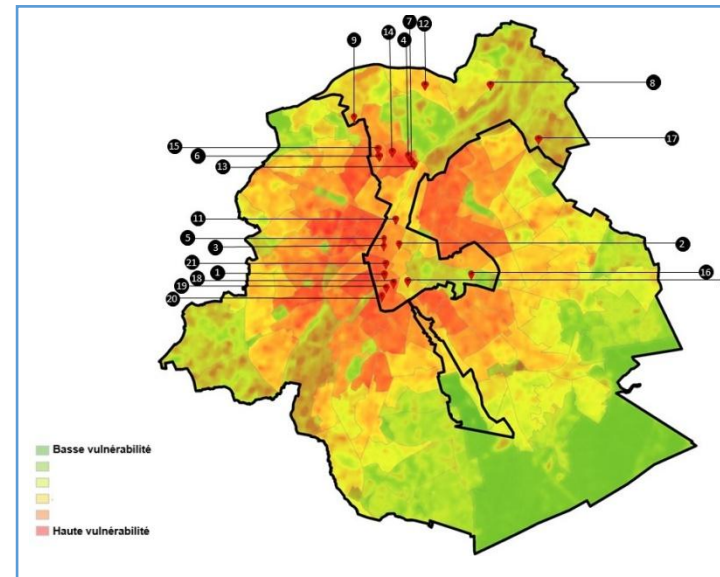
Keywords: field validation, aerial triangulation, LIDAR, georeferencing

Level of maturity: applied research (ongoing)

- Context: European cities are facing severe drought and intensive heat waves during summers. Investing in urban cooling technologies including nature-based solutions adds value and creates jobs at all scale levels. The characterization of urban heat islands in cities requires crossing the barriers of remote sensing and airborne thermal imagery.
- Analyze the surface temperature data and urban street vegetation to support the decision making for passive cooling in European Cities

- GIS mapping of urban canyons in cities
- Geostatistical interpolation and data fusion techniques.

- **Aerial triangulation** is necessary because we need a balance between highly accurate and low accurate characterization of drought maps and heat in urban canyons heat.
- Therefore, we need to **couple the power of field monitoring technologies to create ground-level contextual dataset for our soils, streets and cities.**



Future Outlook: Ground-based Observation 未来展望：地面观测

1. Infrared Radiometer Measurement 2. Observation Vehicle 1. 红外辐射计测量 2. 观测车



or mounting angle in relation to the target will determine target area. Different combinations produce different target shapes and areas, as shown below.



apogee
INSTRUMENTS

Table 2. Overview of observational instruments from MOVE platform.

Instruments *	Variables	Precisions	Manufacture (Model)
Sport Utility Vehicle	Vehicle Speed	-	Hyundai (Maxcruz)
Ultrasonic Wind Sensor	Wind Speed/Wind Direction	$\pm 0.2 \text{ m s}^{-1}$	Vaisala (WMT703)
GNSS Antenna	Latitude/Longitude, Altitude	$> 3 \text{ m}$	Trimble (NetR9)
Rain Detector	Rain Signal	$\pm 1 \text{ min}$	Vaisala (DRD11A)
Barometer	Pressure	$\pm 0.1 \text{ hPa}$	Vaisala (PTB330)
Temp./Humidity Probe	Air temperature/Humidity	$\pm 0.22 \text{ }^\circ\text{C}/\pm 3\%$	Vaisala (HMP155)
Rain Gauge	Precipitation	$\pm 3\%$	Vaisala (RG13H)
Road Weather Sensors	Surface Temperature	$\pm 0.28 \text{ }^\circ\text{C}$	Vaisala (DSP101, DSC111)
Net Radiometer	SW/LW Radiation	$< 1\%$	Kipp&Zonen (CNR4)
Pyranometer	Solar Radiation (Insolation)	$< 3\%$	Kipp&Zonen (CMP11)

* Each number corresponds to the equipment number shown in Figure 3.

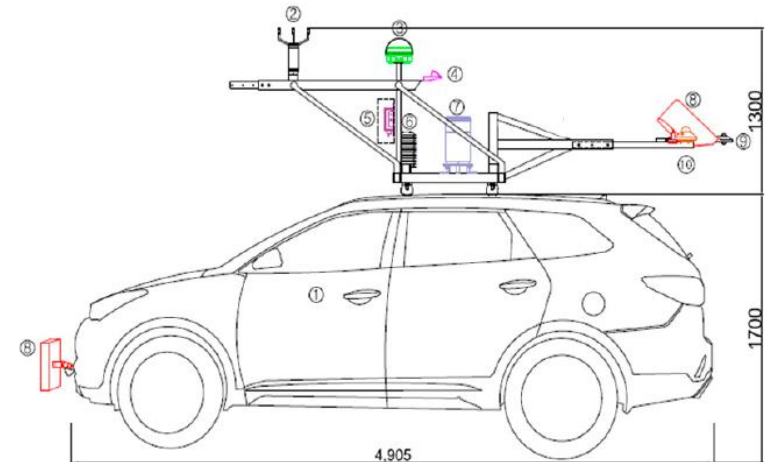
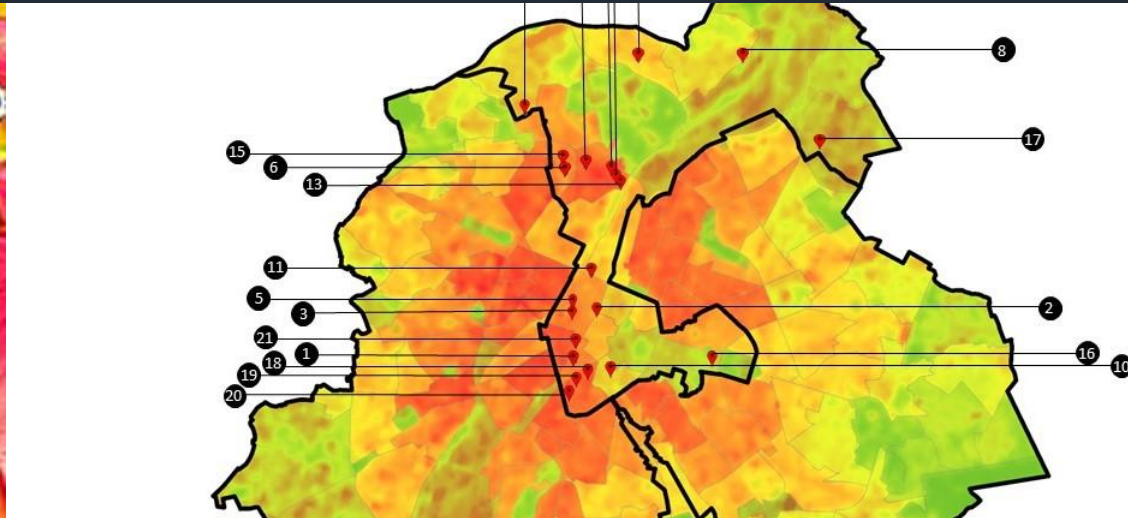


Figure 3. Detailed schematic diagram of the Mobile Observation Vehicle (MOVE) equipped with road weather and meteorological sensors (obtained from Kim et al., 2019^{rom}).



With the rising heat crisis in European cities, combining satellite, drone, and AI-powered forecasts is no longer a luxury—it's our only ground level defense strategy.



随着欧洲城市热浪危机的加剧，结合卫星、无人机和人工智能预测不再是一种奢侈——这是我们唯一的地面防御策略。

Prof. Dr. Shady Attia

*Sustainable Building Design Lab, UEE,
Applied Sciences, University of Liège, Belgium
shady.attia@uliege.be*

 /in/shady-attia-14352a7
 /www.shadyattia.org

30/30

Multimodal Urban Heat Island Detection and Forecasting for Sustainable Cooling in Cities



Attia 阿提亚
Belgium



Prof. Dr. Shady Attia

*Sustainable Building Design Lab, UEE,
School of Engineering, University of Liège, Belgium
shady.attia@uliege.be*



[/in/shady-attia-14352a7](https://www.linkedin.com/in/shady-attia-14352a7)



[/www.shadyattia.org](http://www.shadyattia.org)



YouTube



www.sbd.uliege.be



www.researchgate.net/profile/Shady-Attia

30/30