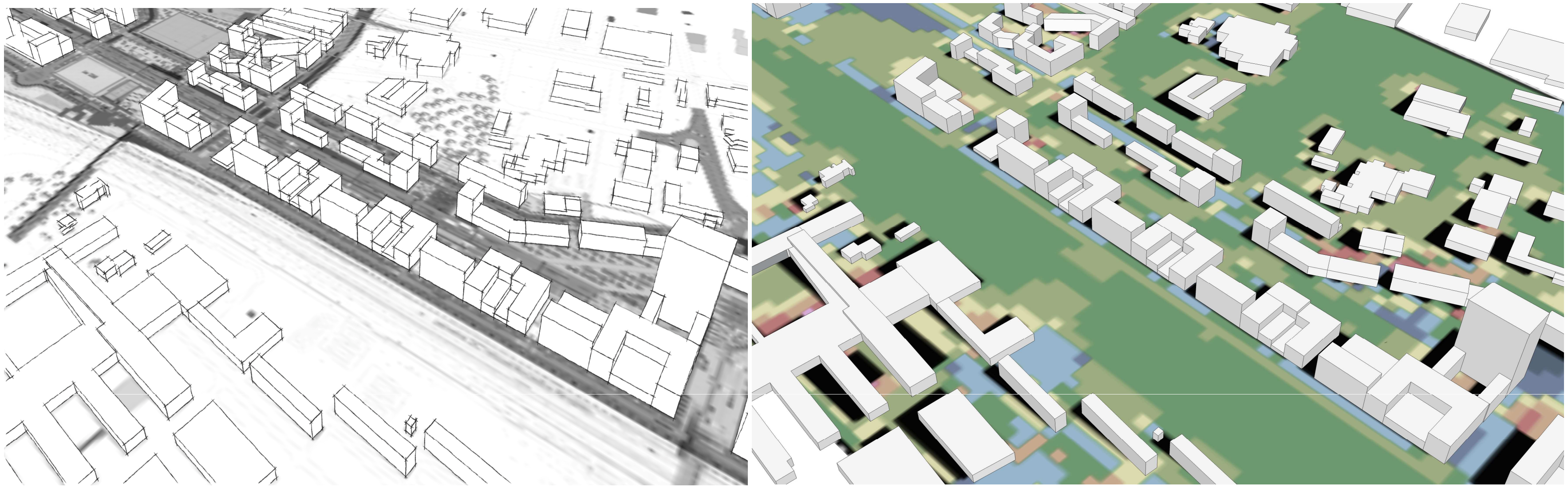

Creating Urban Cool Islands effects for summer season in Toulouse new area

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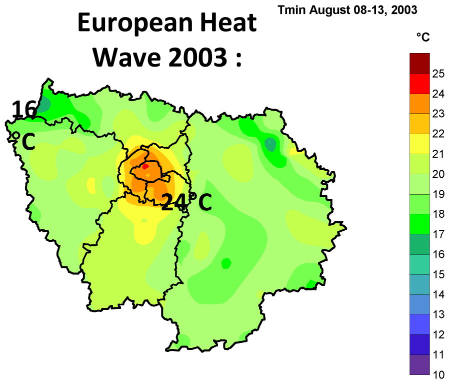
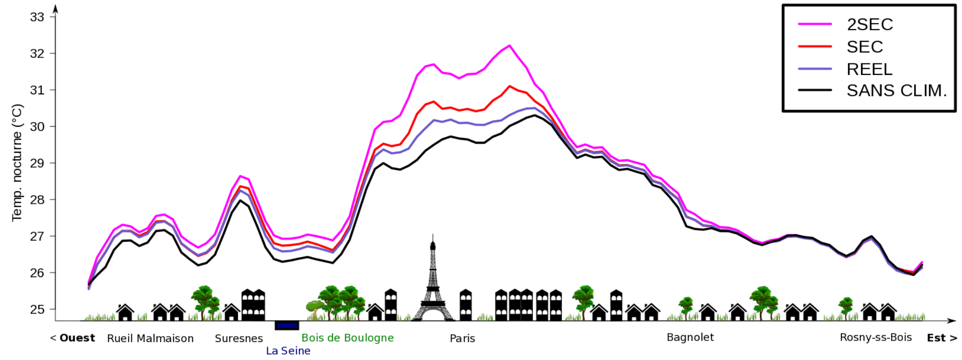
Toulouse 20th July 2015

European Heat Wave 2003 :





Source: Météo-France

- **Cities currently concentrate more than half of the world population**. In France, around 80%.
- Current urbanization models is marked by **important changes in the natural surfaces and in the built morphology**, altering thermal, moisture and aerodynamic properties of these environments. **Cities often present average temperatures higher than temperatures on their outskirts or in the countryside**
- **Urban heat islands** worsen episodes of heat waves in cities.
- The consequences of the UHI effects can lead to the reduction of the efficiency of passive cooling modes, the increase of air pollution, the increase of discomfort, important risks for human health and a significant increase of energy demand in buildings.

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Objective

- French National research Project “Urban Cool Islands” discussed with urban planners and investors, procedures aiming to incorporate a set of reasoned measures of local climate adaptation to a particular new urban area in the city of Toulouse that will be set as landmark reference.

- This research aims at analysing and comparing different adapted and resilient urban design strategies to provide support for their application in the particular case of the Montaudran district plan at Toulouse, focusing on mitigating UHI effects in summer season conditions.

- Our study approach aims at combining knowledge from theoretical and applied research to local urbanism decisions, integrating the evaluation of planners demand, compatibles strategies, microclimate modelling and energy impact estimation of a certain number of design choices.

Method

Three main methodological steps :

① **Assessment of the urban plan proposed by the local practitioners** regarding its design opportunities and constraints toward climate adaptation and creation of urban cool islands for summer season based on specific literature review;

② **Definition of a set of urban adaptations of the initial plan** based on the local plan guidelines and on main microclimate adapting measures;

③ **Analysis of the initial urban plan and its variations** regarding their microclimate and energy effects using computer-modelling simulations.

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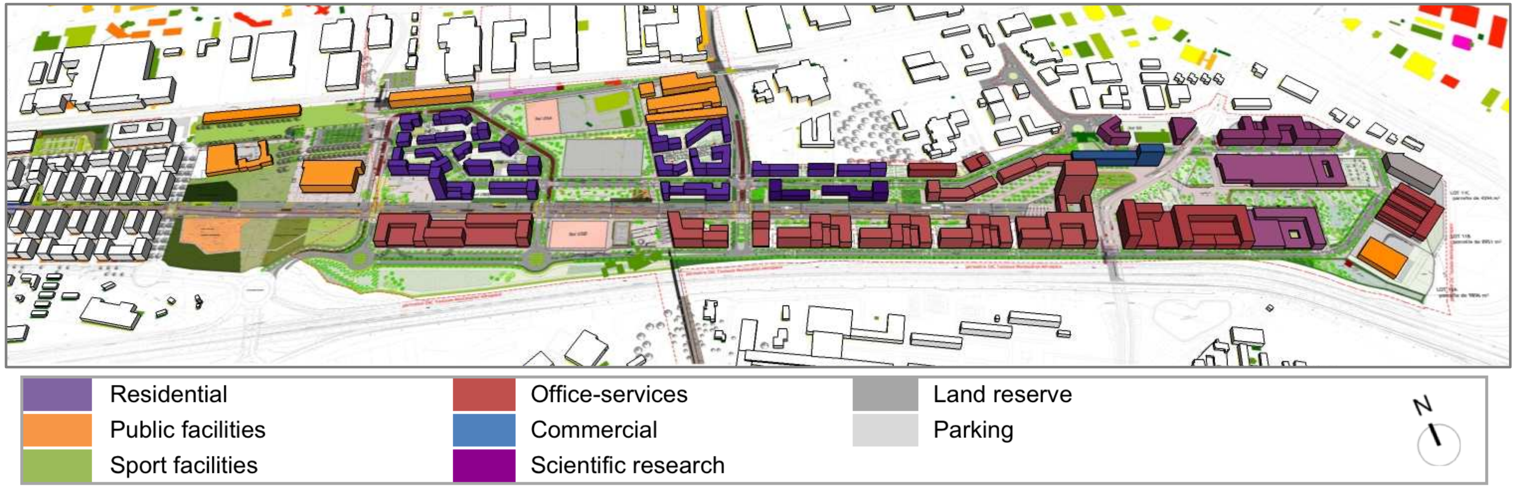
Montaudran Aerospace Valley

Montaudran lays into the greenway of the Rangueil university campus.

Montaudran Aerospace Valley

- District of 56ha at the southeast of Toulouse;
- It will replace the historical Montaudran airport, one of the first airmail services in the world;
- It holds a 1.8km long and 30m wide emblematic tarmac;
- This tarmac and its surroundings will be refurbished and transformed into a mixed-used urban site, with residential buildings, commercial, sport, educational, scientific and cultural activities;
- Sustainable-oriented urban planning.



Montaudran Aerospace Valley

Montaudran district plan presents few linking points to support the integration of important devices and strategies to reduce UHI effects:

a) Concerning the **planning opportunities**:

- wide potential area of green spaces and the use of local vegetation;
- Potential of rainfall collection by hydraulic valley and pond systems;
- possible integration water fountain or sprayer along and at the borders the ancient runway (at the central square and playground square);
- height of buildings at the border of the road could still be reasonably modified.

b) Regarding the **planning constraints**:

- important footprint of asphalt surfaces including the 1.8km long to 30m wide of the ancient runway should produce an important overheating zone;
- urban form and implantation of buildings previously defined may not be modified.
- cool paving materials is not primarily envisaged due to its high investment cost;
- important commercial and services building area where the use of air-conditioned is primarily imposed;

Toulouse Temperate Climate

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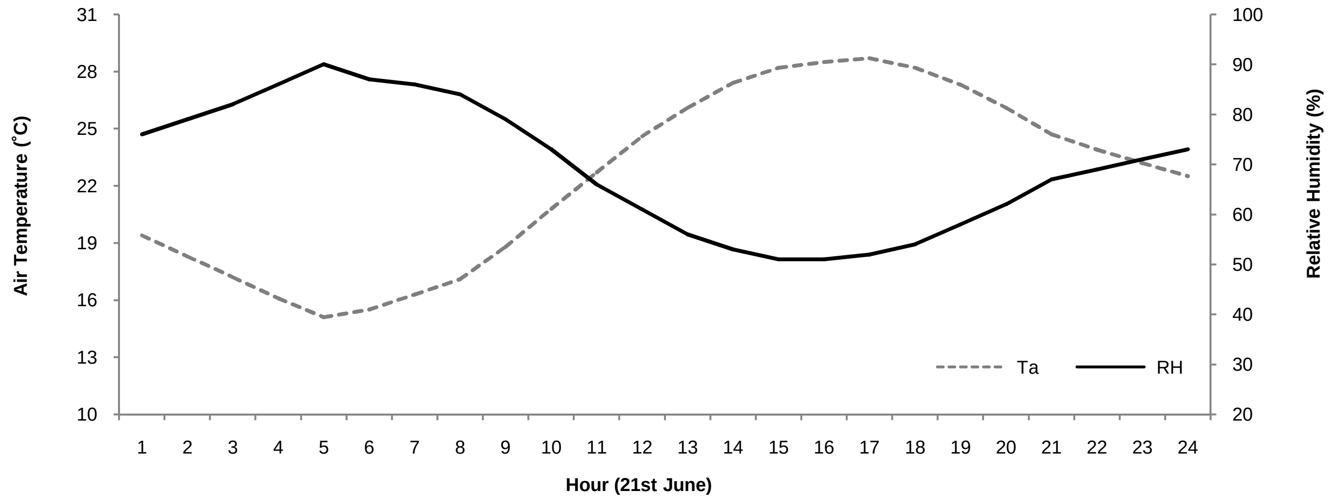
- Toulouse is a city situated in the south western of France;
- It is located at 263m of altitude and it lies on the banks of the river Garonne;
- Temperate with oceanic, Mediterranean and continental influences, characterized by very warm and dry summers;

- Typical day of summer: air temperature can fluctuate between 15˚C with 90% of relative air humidity early in the morning and 30˚C with 50% of relative humidity late in the afternoon;

- Summer season in Toulouse is often marked by extreme hot waves episodes with temperatures that can rise above 40˚C. In urban environments, this thermal conditions can be even more exacerbated due to the strong mineralization of urban surfaces.



Elaboration of reference urban scenarios

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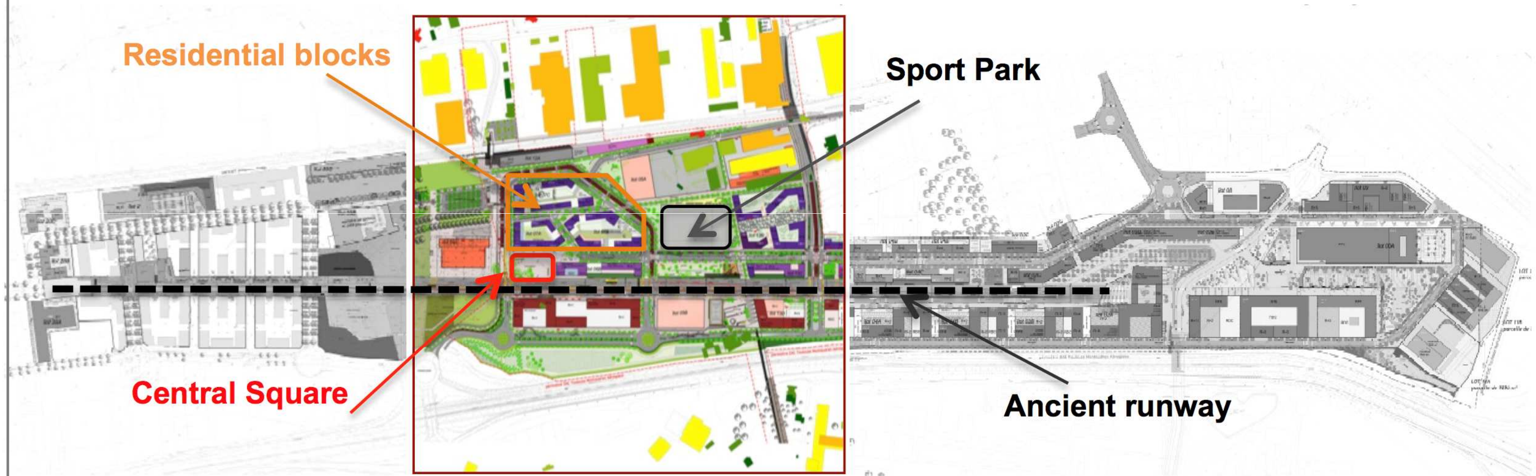
Evaluation of public spaces presenting potential use in summer season : public squares, sport and recreational parks as well as the main student residential blocks of buildings, for which the use of air-conditioned was not anticipated.



Research focused on the main well-known factors contributing to UHI in cities.

- Extensively *mineralization* changes thermal properties of surface materials.
- *Absence of vegetation* in urban areas reduces solar masks and cooling effect of trees.
- Geometric factors. Tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated : the "urban canyon effect" (Oke, 1987).

Base case and contrasted scenarios

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From the base case plan, a set of four contrasted scenarios have been evaluated representing **main climate strategies** to mitigate UHI effects:

***Blue* Scenario**: adding water surfaces with fountain next to emblematic road;

***Green* Scenario**: a vegetal density two times stronger than the base case;

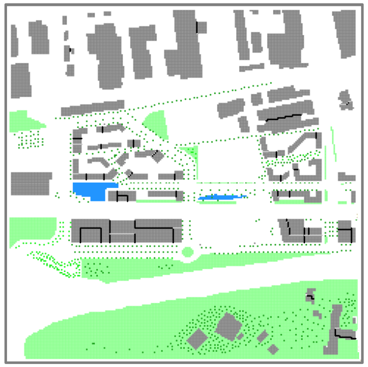
***White* Scenario**: façades and roofs set with very high level of albedo;

***Aspect* Scenario**: building Height to street Width ratio (H/W ratio) two times stronger than the base case.

Base case plan

Green scenario

Blue scenario



Aspect scenario

White scenario

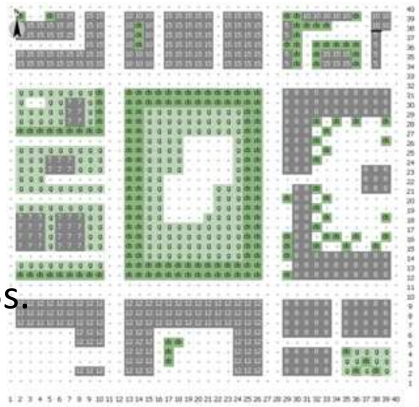
Simulation model

ENVI-met® tool…

- Modelling of an urban climate system complexity;
- Simultaneous and interactive calculations of radiation, thermal

and hydric balance as well as aerodynamics in urban spaces.

- Typical horizontal resolution from 0.5 to 10m
- Typical time frame of 24 to 48 hours and time step of 1 to 5s.



The model includes the calculation of:

- the airflow between buildings,
- the impact of vegetation and water surfaces in the microclimate,
- exchanges between the soil surfaces and building walls,
- bioclimatology and pollutants dispersion (Bruse, 2009).

Two important drawbacks imposed:

- does not allow the complex energy calculation of buildings,
- calculation time is prohibitive (typically more than 15 days of calculations for a single simulated day of a relatively complex urban scene with a powerful calculator).

ENVI-met remains one of the single models enabling realistic microclimatic simulation.

Urban zone domain comprising 230 x 230 x 26 grids for a 3m-grid resolution.

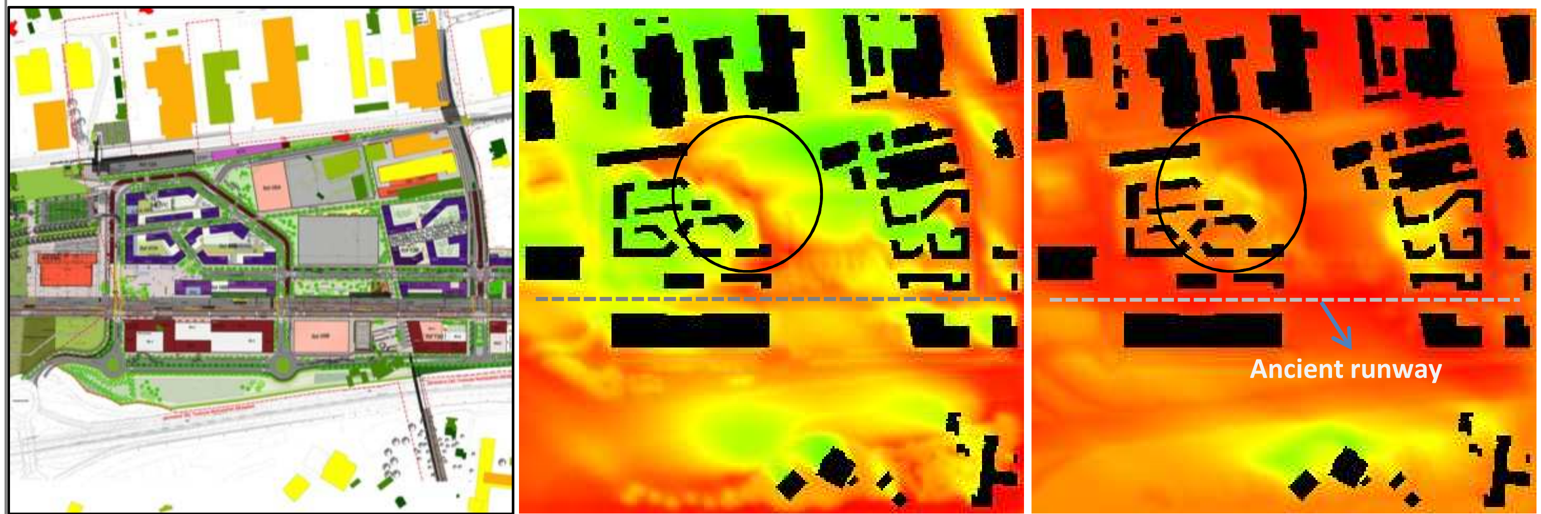
Initial and boundary conditions

- **Meteorological data from Blagnac Airport** – equidistant from the downtown of Toulouse, similar morphology and climate conditions;
- **Hourly weather data for the 21st June** (summer solstice);
- **Simple forcing of air temperature and relative humidity**;
- For the wind speed and direction: a mean value observed by the weather station at ground level;
- Simple logarithmic interpolation – spatially and temporally – for the calculation of the vertical 1D wind profile (lateral and top boundaries conditions imposed to the 3D model);
- Wind direction is kept constant at all levels;
- The humidity profile of the atmosphere is interpolated linearly, according to data observed at the ground level;
- Soil temperature and moisture at three depth levels obtained from weather station.

Montaudran plan – base case

- spatial heterogeneity of air temperature at day and night time;
- higher air temperature over the asphalt roads around the residential blocks and the sportive park;
- lower temperatures inside building blocks, due to the low sky-view-factor (SVF) and to the solar mask effects. The effect is inversed during nighttime;

- Important UHI : the ancient runway, the residential blocks and the central square.



Day time (12h) **Nighttime** (0h)

Microclimate analysis

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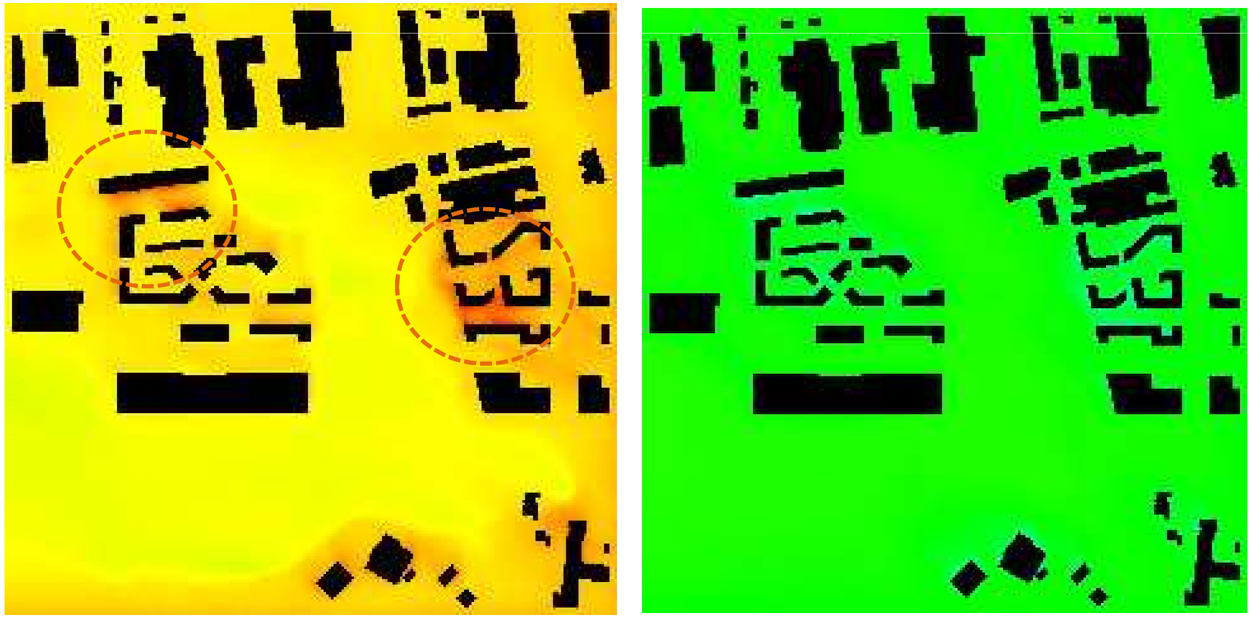
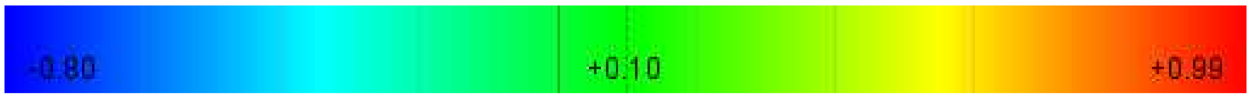
Scenario 1 : « White »

- high albedo surfaces - slightly cooler nights but slightly hotter daytime than base case;
- especially around buildings with a low SVF and surrounded by mineral dark soil surfaces;
- cool façades and roofs may not always represent an optimal strategy for creating urban cool islands, regarding air-temperature. Urban form and structure as well as paving materials must be simultaneously considered.
- In this particular case, light pavement was not initially a possibility for investors.

$$\Delta T_1 = T_{\text{White scenario}} - T_{\text{base case}} \ (^\circ C)$$



Daytime (12h) **Nighttime** (0h)



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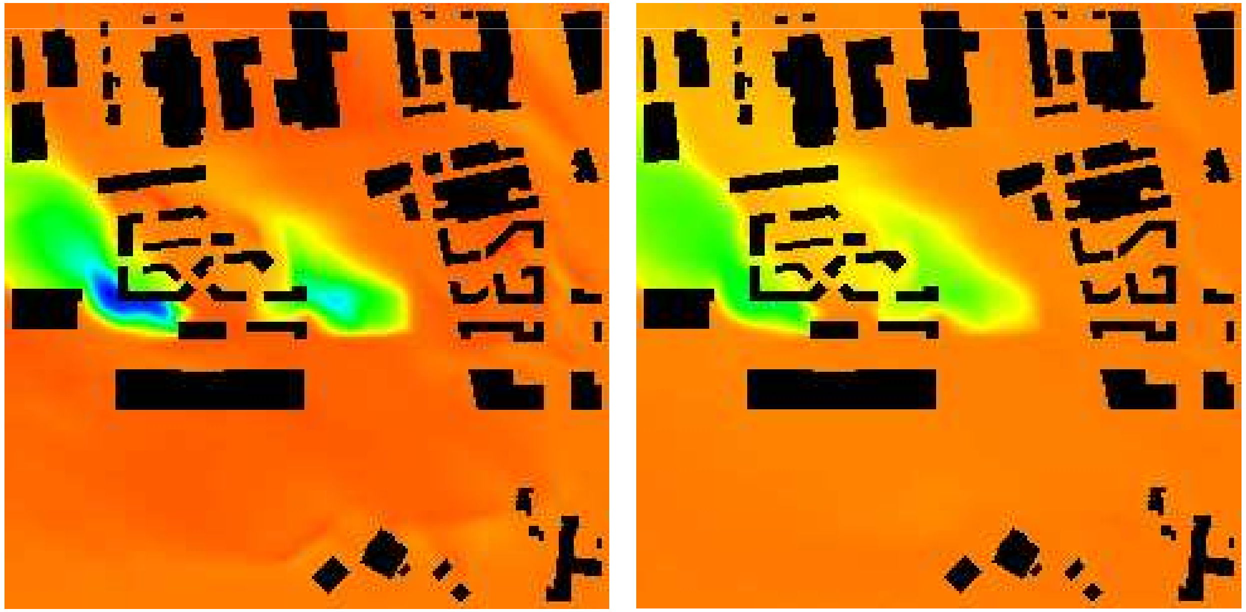
Scenario 2 : « Blue »

- Two water spaces with fountain (central square and playground square) allowed the creation of two important cool islands with up to 6˚C cooler than base case;
- important interaction effect with the wind flow : local air-temperature reduction of 2˚C found on the wind outlet area.

$$\Delta T_1 = T_{\text{Blue scenario}} - T_{\text{base case}}$$



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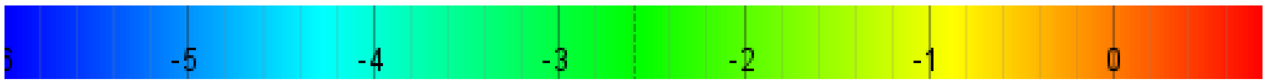

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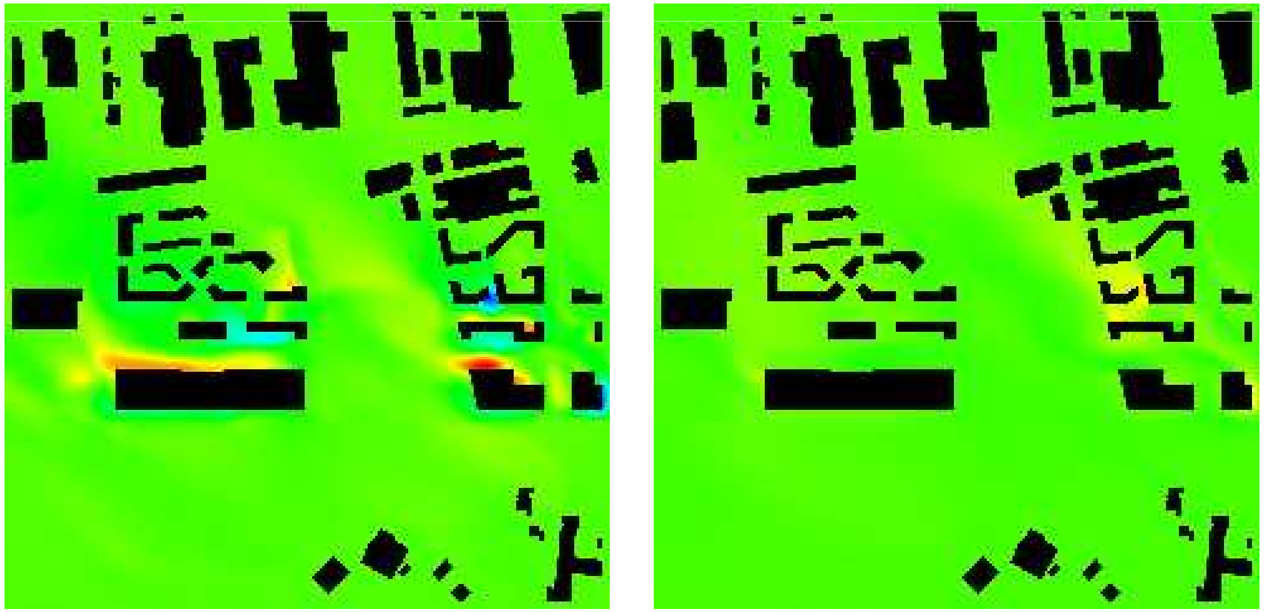
Scenario 3 : « Aspect ratio »

- An aspect ratio two times stronger may produce very punctual heat islands up to 1,5˚C hotter than the base case.
- Spatial homogeneity of air temperature during day and night time.
- Original building implantation does not actually allows a real canyon street effect, which could play decisive role in producing cooler daytime temperatures (by solar mask effect).

$$\Delta T_1 = T_{\text{Aspect scenario}} - T_{\text{base case}}$$



Daytime (12h) **Nighttime** (0h)

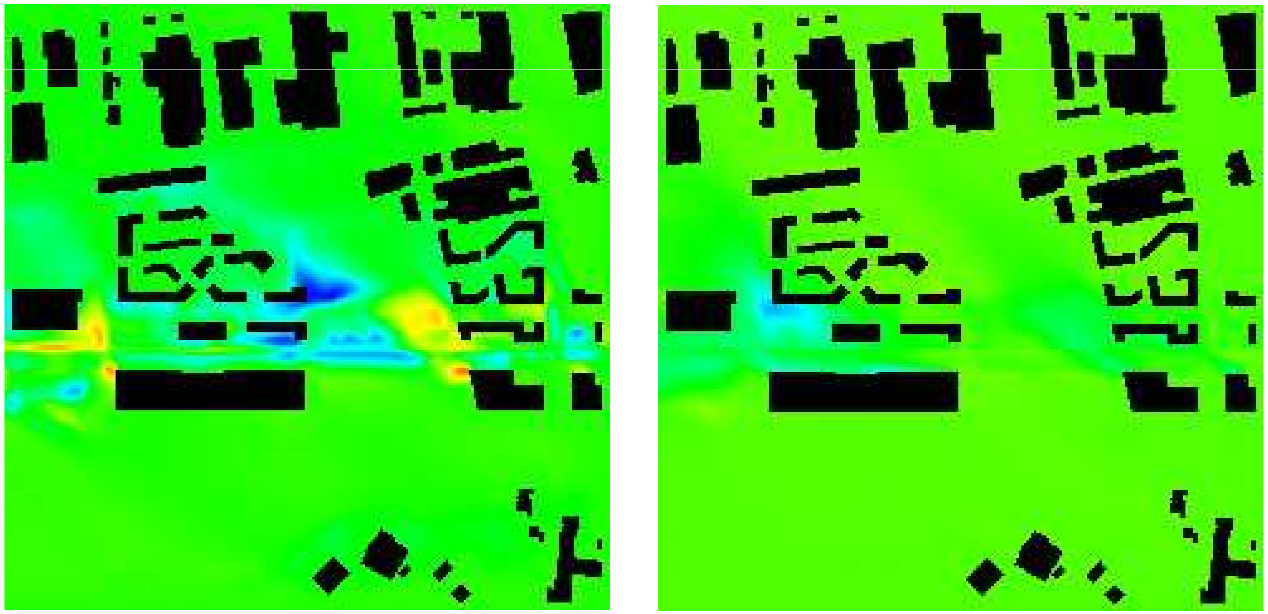
Microclimate analysis

Scenario 3 : « Green »

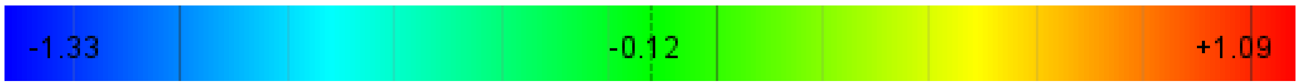
- Applying vegetation two times denser than the base-case allowed creating cool islands punctually along the main road and in the central square.

- No important changes in air-temperature can be however verified in the night compared to the base-case.

$$\Delta T_1 = T_{\text{Green scenario}} - T_{\text{Base case}}$$



Daytime (12h) **Nighttime** (0h)



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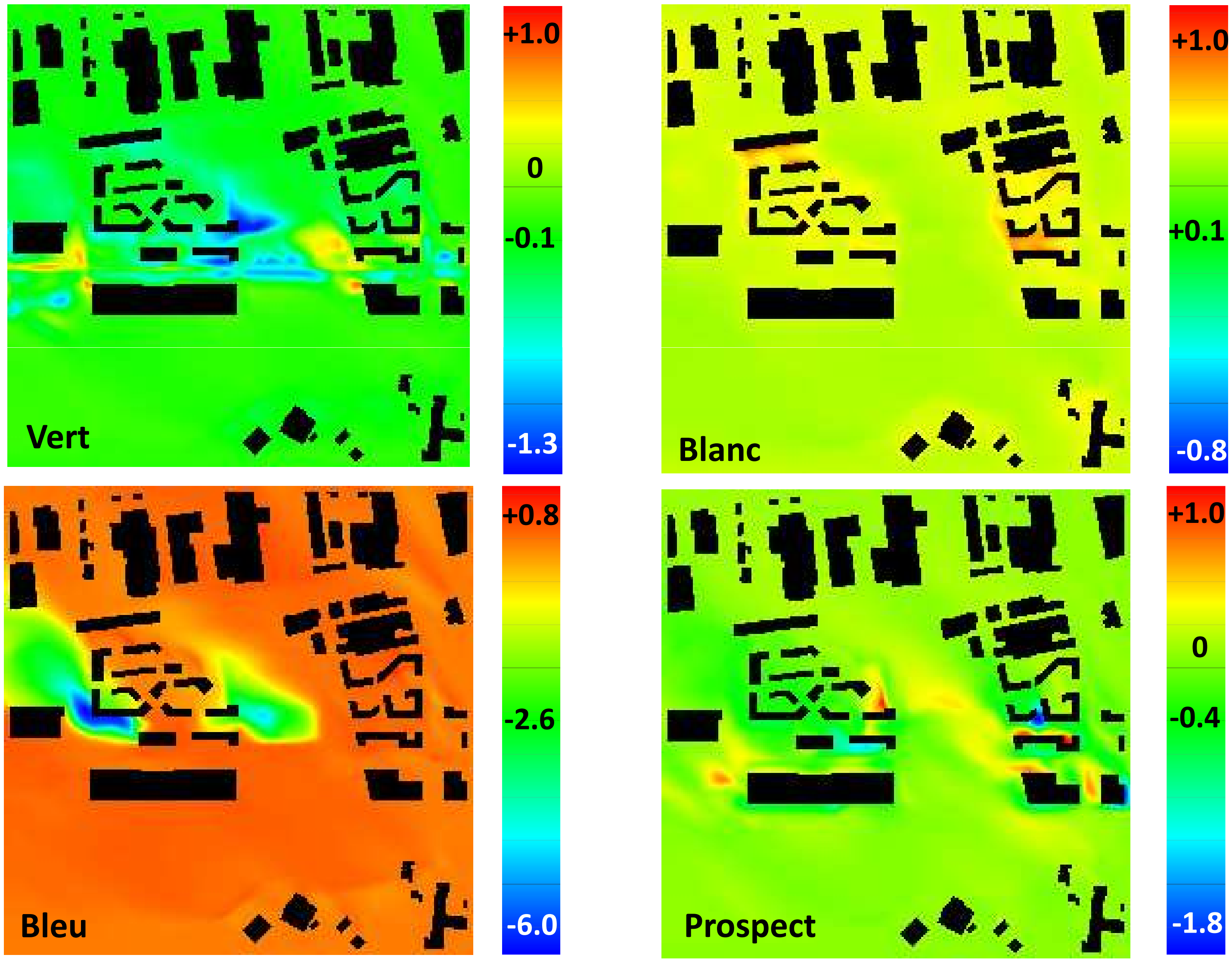
Comparison between scenarios for air temperature at daytime (˚C)



Microclimate analysis

- Introduction
- Objective
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- Resultats
- **Conclusions**

- Cities are complex systems with a wide range of interactive factors on changing urban climate. It still remains very difficult to measure and distinguish their isolated effect, despite of the many statements found in specific literature about UHI.
- On-going applied research project that aims at evaluating climate-adapting devices to mitigate the UHI effects in summer season for the new urban plan of Toulouse Montaudran district.
- Working with a real urban design in progress means copy with its program, constraints and opportunities;
- Referential contrasted scenarios approach instead of multiple punctual actions at a time;
- Numerical simulations allowed comparing devices and their influence on daytime and nighttime UHI, while taking into account their response to an existing urban plan.
- **The use of high water fountains coupled with airflow not only creates punctual cool islands, as expected, but also amplifies considerably the effect in the downwind areas.**
- The impact of important factors such as the aspect (H/W) ratio and albedo, produced way less impact on mitigating UHI effects than devices such as vegetation and water spaces.
- **Factors such as the coverage of urban vegetation and water spaces are important devices that could directly affect on-going design process by decision makers**, but should be carefully studied for each case. That is where policies and programs to reduce the impacts of heat islands – and achieve related environmental and energy-savings goals – can be most effective.

Thank you for your attention!

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