Role of Vegetation, urban morphology and building rise in air quality and urban heat island: simulations in five Parisian neighborhoods

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INTRODUCTION

The European heat wave in 2003 has evidenced the vulnerability of cities to a warmer climate. France experienced an abnormally high death rate of 14 800 people especially in urban environments[1]. Besides the unusually high temperatures, exposure to particulate pollution increases cardiovascular mortality during the summer[2].

- Municipalities have to deal with both air pollution and urban heat island.
- Cities planners usually treat both problems separately, leading to antagonisms measures. For instance, trees seem to mitigate urban heat island (UHI), but may increase pollutants concentrations.

Objective

This study aims to understand what influence vegetation, urban morphology and building rise can have on temperature and air quality.

METHOD

1. Selection of the study areas: The typology chosen is based on morphology, architecture period, materials and construction techniques[3].

Typology **1800** Le Marais | Typology **1850** Le Faubourg | Typology **1914** Le Chaillot | Typology **1939** Le Saint-Fargeau | Typology **1975** De la Gare

Fig 1. Typologies have been characterized by its energy consumption and emissions of greenhouse gases linked to heating homes

2. Development of 4 scenarios:
   - S1. No trees
   - S2. No trees + 2 story addition
   - S3. Neighborhood with trees + 2 story addition
   - S4. Scenario S3 + green roofs on all buildings

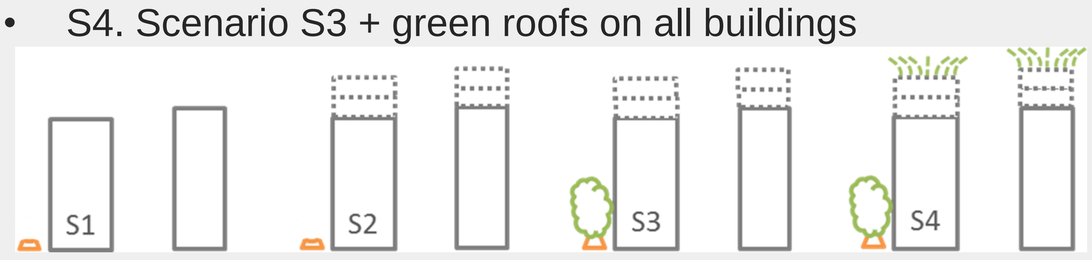

Fig. 2. Sketches of the four scenarios: S1, S2, S3 & S4

3. Simulation in ENVI-met 3.1: We use the 2003 heat wave as a reference for our simulation.

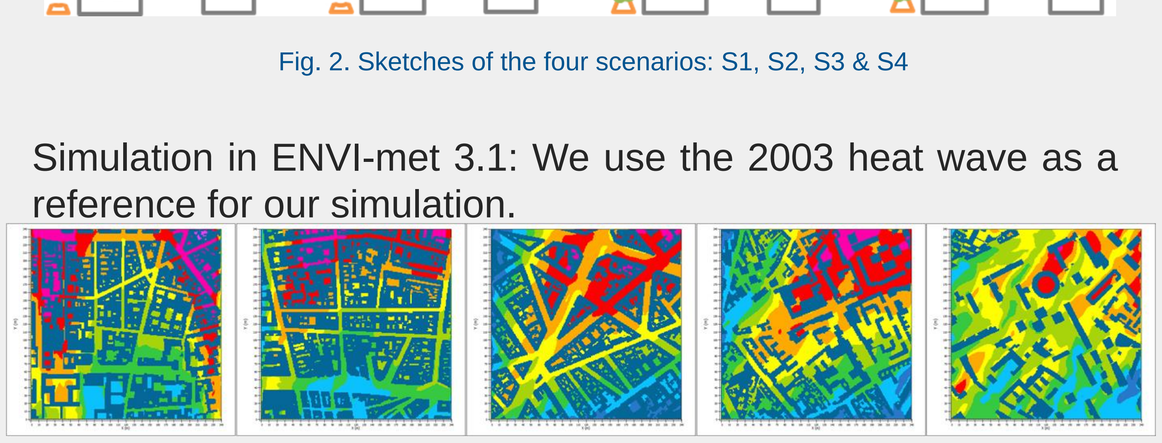

Fig 3. Potential temperature for five typologies simulated in diagnostic stage (D).

RESULTS

For studying UHI, potential temperature (°C) was taken as parameter of comparison. Pollution was studied through PM_{10}.

Potential temperature

The 2 story addition as well as the trees produce a decrease in sky view factor (SVF+V) causing:

- An increase of the shade, a decrease of solar direct radiation.
- A decrease in potential temperature (at z = 1.2 m).

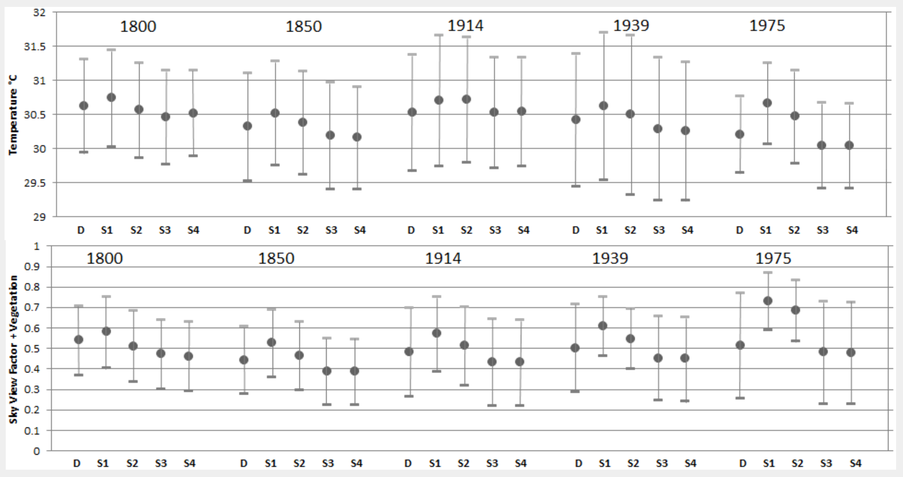

Fig 4. Temperature and SVF+V for the five typologies diagnostic (D) and scenarios S1, S2, S3 & S4

PM_{10} concentrations

The concentrations in PM_{10} showed a slight inversed trend.

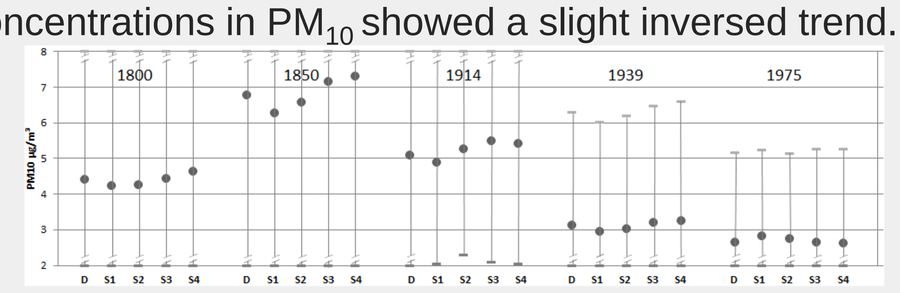

Fig 5. PM_{10} concentrations for the five typologies diagnostic (D) and scenarios S1, S2, S3 & S4

Comparison

Only 3 of 20 scenarios lead to a decrease of temperature and PM_{10} concentrations

D	S1		S2		S3		S4	
	MPT	MPM_{10}	MPT	MPM_{10}	MPT	MPM_{10}	MPT	MPM_{10}
1800	x	√	√	√	√	x	√	x
1850	x	√	x	√	√	x	√	x
1914	x	√	x	x	x	x	x	x
1939	x	√	x	√	√	x	√	x
1975	x	x	x	x	√	√	√	√

Fig 6. Comparison of Mean Potential Temperature (MPT) and Mean PM_{10} concentrations (MPM_{10})

CONCLUSION

Antagonisms between scenarios have been identified regarding UHI and air pollution:

- The S1 are broadly good for air quality, but bad for UHI.
- S3 & S4 are broadly good for UHI, but generally bad for air quality.

There is a necessity to find synergetic solution to treat both UHI and air pollution.

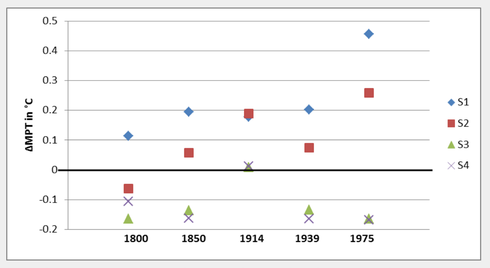

Fig 7. Scenarios of variations of Mean Potential Temperature (ΔMPT) by typology

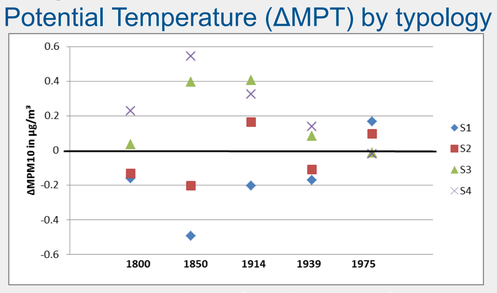

Fig 8. Scenarios of variations of Mean PM_{10} (ΔMPM_{10}) by typology

Acknowledgements:

The JOAQUIN project is supported by INTERREG IV-B North West Europe (www.nweurope.eu)

[1] INVS, 2003. Impact sanitaire de la vague de chaleur d'août 2003 en France. Bilan et perspectives. Institut de veille sanitaire, département santé environnement.

[2] Pascal et al., 2014. Short-term impacts of particulate matter (PM_{10},$PM_{10-2.5}$,$PM_{2.5}$) on mortality in nine French cities. Atmospheric Environment 95:175-184

[3] APUR, 2007. Consommations d'énergie et émissions de gaz à effet de serre liées au chauffage des résidences principales parisiennes. Atelier Parisien d'Urbanisme.

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Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B
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