Urban expansion impact on Heat Island in Lyon metropolitan area

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1 Introduction - Context and motivation

Lyon metropolitan area is located in the centre-east of France, in the Rhone-Alps region. Two rivers flow through and converge at the southern side of the city. In the lower part its altitude is only 170 m, but three hills with altitudes around 250-300 meters surround the city. Lyon metropolitan area is the second in France with 1 300 000 citizens and an important urban growth (for 2030 1 450 000 citizens are predicted). The last study of Lyon Urban Agency shows that, between 2000 and 2010, the city lost 4 percent of its non-urban surface, due to the extension of infrastructures and economic activity areas into the peri-urban area. Since 2009 Greater Lyon takes part in climate protection strategy and the Urban Heat Island (UHI) is one of the key issues of its climate change adaptation policies. The heat wave in 2003 proved that extreme climate events provoke an increase of mortality in urban area. One essential question for the Greater Lyon is how land cover impacts urban climate and population comfort and health. Urban climate modelling is essential to enhance the knowledge of this local phenomenon as there are very few measurements and no previous studies available to describe the Greater Lyon UHI. The aim of the present study is to estimate how the urban growth of the last decades have strengthened UHI by comparing the temperature distribution resulting from the 1975 urban area with the current one. It also presents the impact of data land cover resolution on temperature distribution in Lyon metropolitan area obtained from climate modelling.

2 Methodology

2.1 Models

Due to the lack of meteorological measurements in the urban area in this study simulation results issued from Meso NH model are used in order to characterize the UHI in Lyon metropolitan area. Meso NH is coupled with a surface model, Surfex, that integrates an urban component TEB.

2.1.1 Atmospheric model: Meso NH

Meso NH is a non hydrostatic mesoscale atmospheric model that has been developed by the Laboratoire d'Aérologie and by CNRM GAME. It is based on non hydrostatic system of equations and can be used from large to small scales. It has a complete set of physical parameterizations and is coupled to the surface model Surfex to represent the ground atmosphere interactions. Besides, it allows a multiscale approach through a grid nesting technique.

2.1.2 Land surface model: Surfex

Surfex (V. Masson et al., 2013) is a platform that incorporates four components to compute the exchange of energy and mass between four different types of surfaces and the atmosphere. In Surfex, each model grid box is represented by these four surface types: sea or ocean, water bodies such as lakes, urban areas and nature (soil and vegetation). Each surface type is modeled with a specific surface model and the total flux of the grid box results from the addition of the individual fluxes weighted by their respective fraction.

Town Energy Balance model: TEB TEB (V. Masson, 2000) is a physically-based town energy budget scheme for atmospheric meso scale models. It works as the urban component of Surfex platform and allows the calculation of radiative budgets and heat fluxes. TEB scheme is built on a canyon approach that is generalized to reproduce larger scales. In each grid mesh, the urban fraction is assimilated to a specific urban canyon with the following main parameters: height and width of the buildings; thickness, albedo, emissivity and heat capacity of roofs, roads and walls. The vegetation (gardens, parks) is also described. The runs are initialized with NWP model AROME reanalysis for a given day. AROME resolution is 2.5 km.

2.2 Surface data

For the high resolution modelling, the son grid is based on an accurate surface database that includes a description of the urban fraction at a 250m resolution. Outside this grid, ECOCLIMAP is used as land surface reference.

2.2.1 Ecoclimap

ECOCLIMAP (S. Faroux et al., 2013), describes land surface over Europe using an ecosystem classification and a coherent set of land surface parameters at a kilometric resolution. This description of the land cover is used within the father grid.

2.2.2 Lyon urban surface database

To describe the land cover of the son grid, an appropriate grid is built that includes a percentage of nature, water and town. Then, in the urban fraction, all the parameters related to the buildings, vegetation type and the geometric characteristics of urban canyon are described. To obtain the Greater Lyon land cover characteristics a new database is created. Three land cover bases are combined: the Greater Lyon local urban plan, SPOT Thema and an urban historical database (N. Ferrand, 2010). The urban historical database gives information for each parcel of Lyon metropolitan area for 5 periods: 1950, 1975, 1990, 2000 and 2010. The basic design principles are the same that are used in Spot Thema with the 3 levels of typology to identify the process of urbanization.Land cover changes and dating of the buildings in the Greater Lyon can be obtained from this historical database. The study in Greater Paris MUSCADE (A. Lemonsu et al., 2012) provides information about the materials of each building regarding its date of construction and its use. A local adaptation of this material typology is completed with architects to take into account the main architectural differences between Lyon and Paris.

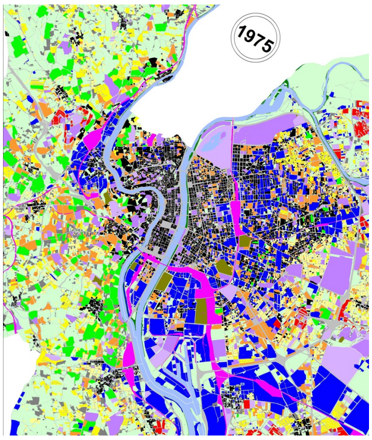

Fig.1. Historical database, Lyon 1975.

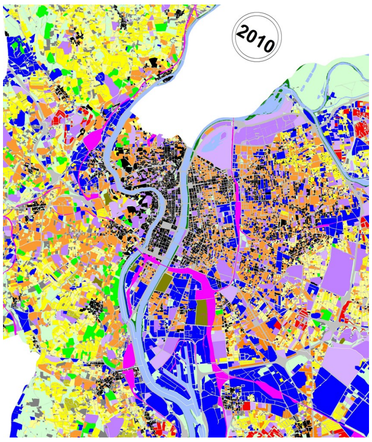

Fig.2. Historical database, Lyon 2010.

3 Results

3.1 Spatial scale effect: contribution of UHI high resolution modelling

The 250m resolution modelling offers the possibility to represent more exactly the rivers influence on UHI which is not seen with ECOCLIMAP. The part of garden is also better represented.

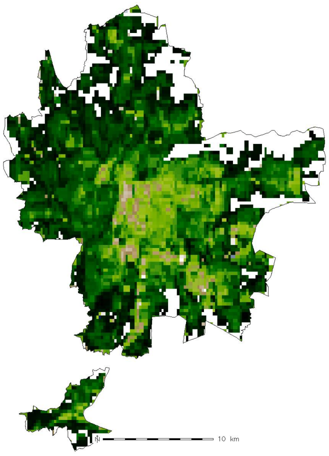

Fig.3. Garden fraction in Greater Lyon.

The two figures below are intermediate results that do not integrate the garden fraction yet. The definitive results will reveal the effect of the urban vegetation has shown on fig.3..

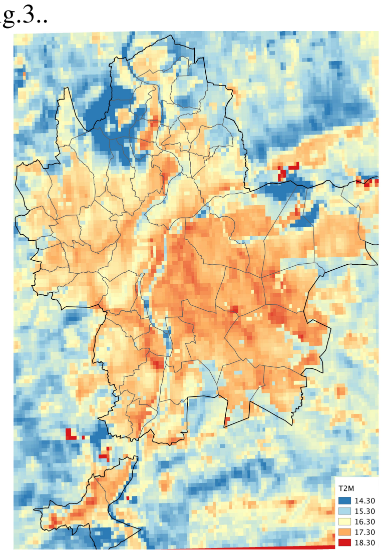

Fig.4. 2 meters air temperature at 09 am 30/04/11.

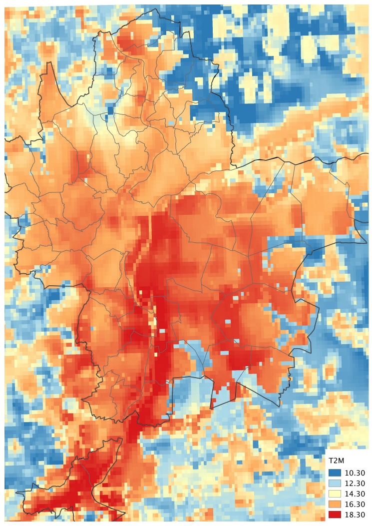

Fig.5. 2 meters air temperature at 22 pm 30/04/11.

3.2 Temporal scale effect: impact of urban growth on UHI 1975 vs 2010

The results are being produced.

4 Conclusion

This study is the first that describes the temperature distribution in the Greater Lyon. An estimation of micro climate changes resulting from urban area expansion is established. Two simulations are compared: one with the 1975 land cover and the second one with the 2010 land cover for the same meteorological conditions of the 2003 heat wave. The differences reveal new zones of higher temperatures induced by urbanization. Simulations based on the current land cover indicate urban zones where UHI hazard is higher, allowing local authorities to define priority actions.