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Urban Climate, Human behavior & Energy consumption: from LCZ mapping to simulation and urban planning (the MapUCE project)

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dated : 5 July 2015

1. Introduction

The MApUCE project aims to integrate in urban policies and most relevant legal documents quantitative data from urban microclimate, climate and energy.

The primary objective of this project is to obtain climate and energy quantitative data from numerical simulations, focusing on urban microclimate and building energy consumption in the residential and service sectors, which represents in France 41% of the final energy consumption. Both aspects are coupled as building energy consumption is highly meteorologically dependent (e.g. domestic heating, air-conditioning) and heat waste impact the Urban Heat Island. We propose to develop, using national databases, a generic and automated method for generating Local Climate Zones (LCZ) for all cities in France, including the urban architectural, geographical and sociological parameters necessary for energy and microclimate simulations.

As will be presented, previous projects on adaptation of cities to climate change have shown that human behavior is a very potent level to address energy consumption reduction, as much as urban forms or architectural technologies. Therefore, in order to further refine the coupled urban climate and energy consumption calculations, we will develop within TEB (and its Building Energy Module) a model of energy consumer behavior.

The second objective of the project is to propose a methodology to integrate quantitative data in urban policies. Lawyers analyze the potential levers in legal and planning documents. A few "best cases" are also studied, in order to evaluate their performances. Finally, based on urban planning agencies requirements, we will define vectors to include quantified energy-climate data to legal urban planning documents. These vectors have to be understandable by urban planners and contain the relevant information.

To meet these challenges, the project is organized around strongly interdisciplinary partners in the following fields: law, urban climate, building energetics, architecture, sociology, geography and meteorology, as well as the national federation of urban planning agencies.

In terms of results, the cross-analysis of input urban parameters and urban micro-climate-energy simulated data will be available on-line as standardized maps for each of the studied cities. The urban parameter production tool as well as the models will be available as open-source. LCZ and associated urban (and social!) indicators may be integrated within the WUDAPT database.

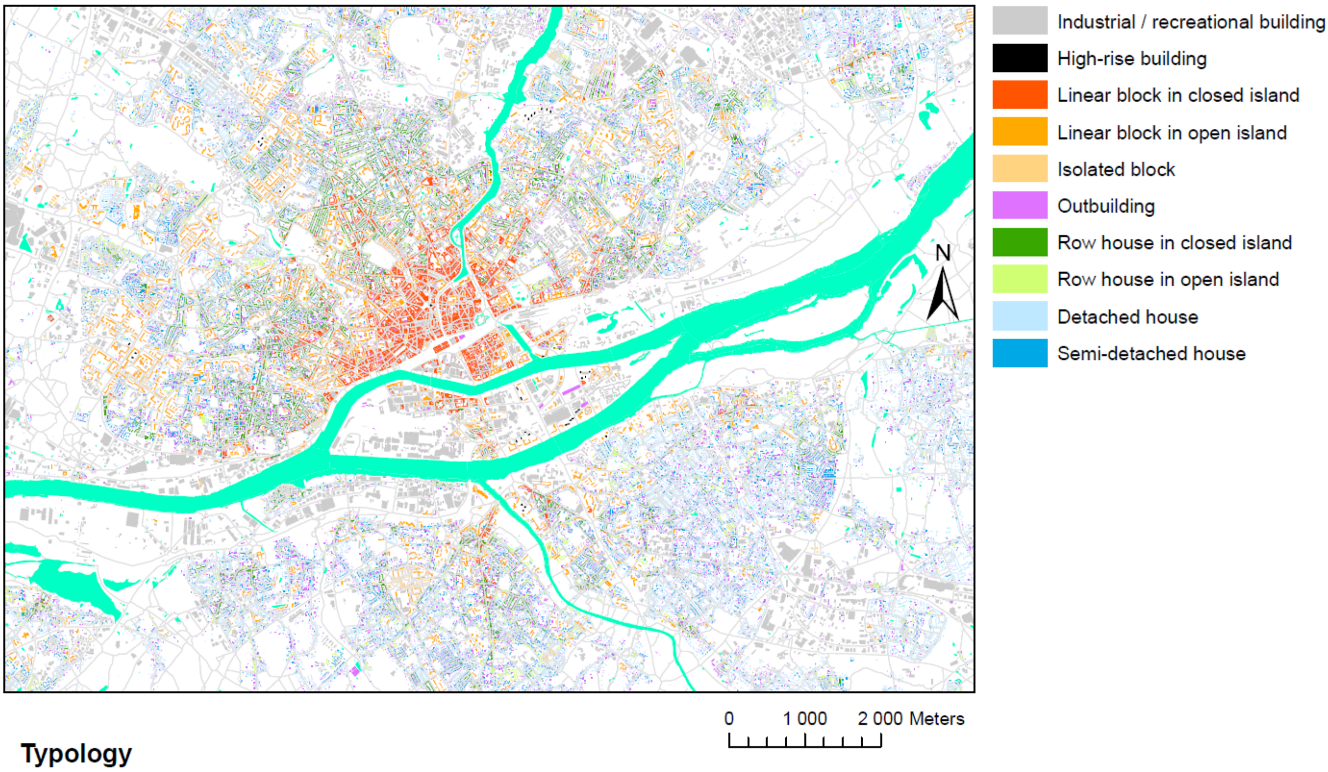

Figure 1 : exemple of typology of each buildings, estimated automatically using a random forest algorithm.

2. From Local Climate Zones (LCZ)...

The objective is to define each neighbourhood from a point of view understandable by both urban planners and modellers. The concept of 'Local Climate Zone' (Stewart & Oke 2012) describes both urban morphology and its impacts on local micro-climate.

An automatic platform under a Geographical Information System is built in order to derive 80 urban & social indicators, at building and neighborhood scale (figures 1 & 2). The methodology is :

1) to use buildings&social national databases

In order to have a methodology available for all cities in France, we have chosen databases that are homogeneous and simply available on the entire country. These databases are at several spatial resolutions: the finest is the building scale, with some morphological information (especially building height and shape) but also some usage information (industrial or not). We have then the parcel scale, with its delimitations for all private domain, and many information about land use (water and road network, vegetation). Using these topographic sources, we compute a new zoning made of the contiguous street-blocks, that can be aggregated then to upper levels to transform it into LCZ (cf infra). Social information is available statistically for surfaces with at least 2000 households each, or on a grid of cells of 200 m by 200 m, with fewer information but useful, like number of inhabitants, or households for instance. Finally, information on architectural technics and methods are available at larger scale (for example, red bricks are usually used in historical construction in south-West of France).

2) to derive the limits of the islets

The islets are continuous street blocks, a scale that is very understandable by urban planners, as it is intimately linked to the structure of the city. In order to define continuous islets, one first aggregates contiguous parcels. Then, as one wishes to include roads and other extra-parcel surfaces in their neighborhoods, a Voronoï algorithm is used to determine the limits between two islets.

3) to compute the indicators

Several indicators, covering morphologic ones (example: mean and distribution of building heights), social ones (age of people and family sizes, buildings uses…), and architectural ones (type of material used for walls or roofs,…) are computed. For further modelling, the typology of each neighborhood is defined, which allows them to be then treated as small LCZ.

Such spatial scale is too small for a LCZ from the point of view of the urban climatologist, true, but this is understandable as such for urban planners, which appropriated the concept of LCZ. Furthermore, as can be seen on figure 2, LCZ of the same colour can be spatially aggregated in order to reflect the concept of urban climatologists LCZ concept better. The advantage is that there is more details for each LCZ indicator (e.g. mean building height in the LCZ) when spatial scale is smaller.

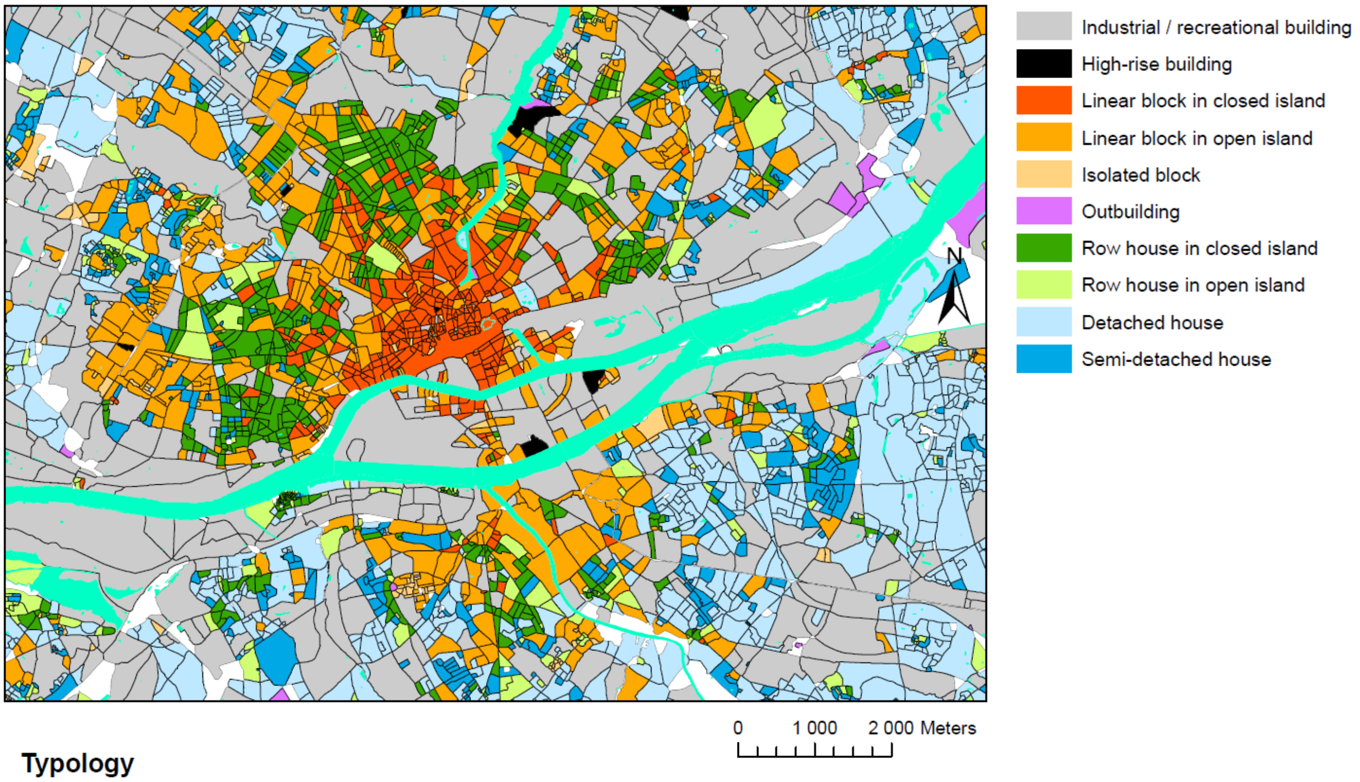

Figure 2 : exemple of typology of each LCZ, estimated automatically from the typology of buildings within.

3. … for modelling of behaviours, energy and micro-climate ...

Past projects (e.g. MUSCADE, Masson et al 2014) showed that energy consumption is more reduced by behaviours than buildings improvements.

The objective is to model behaviour, using existing specific databases on relationship between energy consumption & inhabitants practices (e.g. from ENERGIHAB project). Example of behaviours are: target temperature for heating or air-conditioning, occupancy of the building, regulation of heating systems, closing/ opening the windows at night, possession of equipment, frequency of use of some appliances (i.e. washing machine) etc.. The method to model each of these behaviour or use of the building is to link them to typologies of household and housing using a statistical approach (logistic regression), as these are data we can project (with some hypotheses) at LCZ scale.

Behaviour = function (household, housing)

The behavioural model created in the basis of the ENERGIHAB database (referred to the Ile the France Region only) will be tested and validated on other databases at the national scale, and finally translated to the islet scale through successive adjustments.

The main advantage of islets for such estimation is that they are more homogeneous in their content for housing and households: most of the time, contiguous parcels group similar activities. The comparison (figure 3) with a regular grid of 250m x 250m for diversity of indicators such as building levels (lower than or upper than 2, grey scale), building usage (residential or not, colors), reveals that islets are more specialized in their content. This, plus the fact that some proxies are precomputed at this scale (number of inhabitants, households, collective housing …) allows for an more efficient estimation method of households behavior.

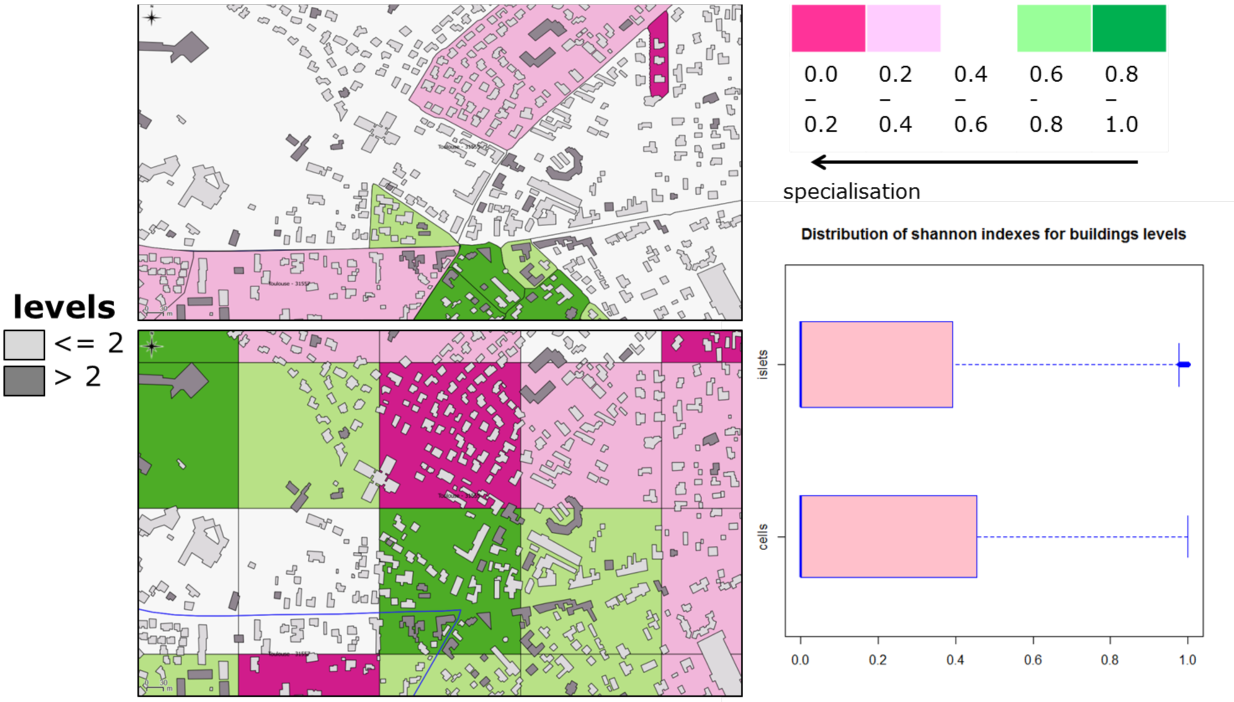

Figure 3. Comparing specialization of cells versus islets through Shannon index.

Behaviours will be included in **TEB-BEM** (Masson et al 2000, Bueno et al 2012, Pigeon et al 2014), a model for urban micro-climate. This will allow to simulate urban micro-climate as well as energy consumptions for buildings. As input data, it will use the urban & social indicators at islet scale that have been calculated automatically with the GIS software for 81 French cities.

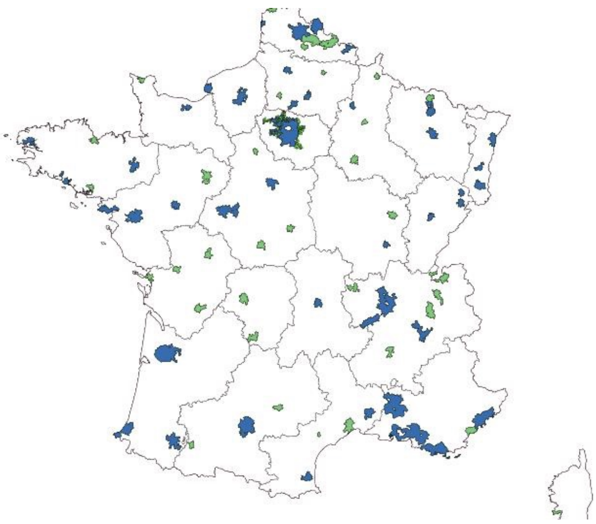

Fig. 4 : The cities where for which the simulations will be done

4. … to Urban planning and laws

Besides the tasks related to the production of climate and energy consumption data, research on how to integrate energy, micro-climate and climate change issues in urban planning are also being addressed in parallel.

This section of the project is titled “Urban planning plans: general framework and transfer”. It is composed by four tasks dealing with: the legal French framework analysis; the analysis of “exemplary cases” from the point of view of their governance and the legal translation of local actions; the analysis of the experience of use and needs of data by the French planning agencies; and finally the development of transfer tools adapted to the French urban planning standards.

In this sense, more than twenty planning legal tools have been analyzed from the French urban planning and land management laws; the energy and climate planning documents; documents from the sustainable development field; and finally some specific scoping papers.

The **legal analysis** shows that:

- Legislative text provides that the majority of those tools can or should include actions related with mitigation and/or adaptation to the climate change.
- However, each of them is submitted to some levers and obstacles as the precision of the applicable actions, the legal force of the measures and the cross competencies within the stackeholders.

The study concludes that to efficiently take into account microclimate, building energy consumption and energy human behaviour, actions should be addressed not only by one but with several complementary legal documents.

The objective of the “**exemplary cases**" task, is to analyze the levers that permit the transfer from climatic knowledge to practices. And also, to understand what is the applicable scale of such information and what are the obstacles. In summary, why the transfer of climate information is successfully done in some places and not in others?

At the beginning a large panel of cases were identified in France and abroad (Europe, America, Asia and Oceania) based on scientific and Grey literature as well as some preliminary interviews with researchers. In a second time the focus was put on a panel of cases that seemed particularly interesting: Germany and Japan due to their high degree of expertise at both research and implementation levels; Spain and Netherlands due to an incipient practice in this sense. In France the cities of Paris, Grenoble, Lyon, Marseille, Frontignan and Agen were also deeply analyzed.

Methodologically, the analysis was based on literature, institutional websites and interviews with both practitioners and producers of climatic data, almost always researchers. Three types of targets were considered: implementation at the urban politics level trough planning documents, implementation at the operational level (operations of urban spaces) and the development of dedicated agencies and transfer tools (climatic maps or atlas).

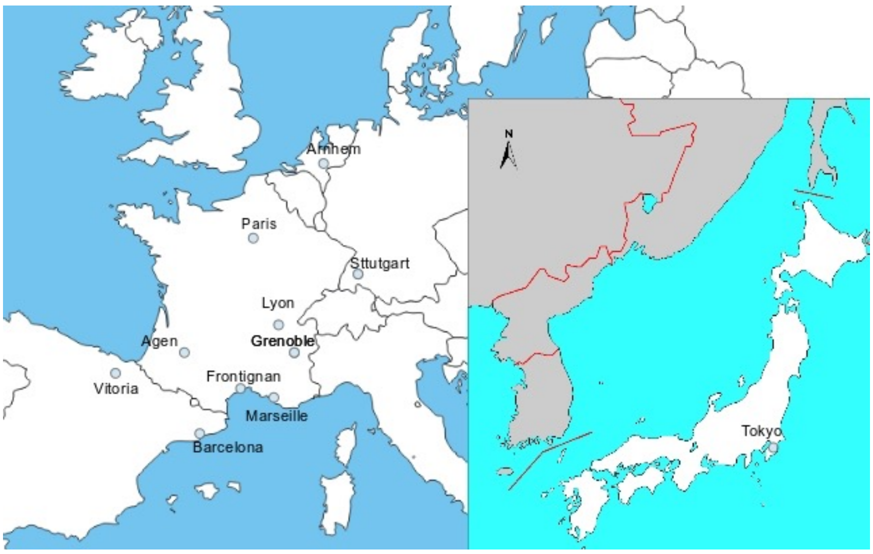

Fig. 5 : map of the cities that were studied as 'exemplary cases'

The analysis of **exemplary cases** showed that, financial means are not the main factor that inhibits the consideration of energy and climate in city planning. Good practices seem being favored by key persons that make the link between several city services and some other institutions (as laboratories). This work is being completed in coordination with the urban environmental lawyers team that analyze for the same study cases the legal framework at the national, regional and local levels.

To obtain inputs to the tasks related with the exemplary cases and the transfer tools, a **survey to all 51 French urban planning agencies** has been done. The objective was to analyze how climate and energy issues are being integrated in city planning and urban design and to caracterize potential user needs. 25 agencies have been answer the survey showing a large heterogeneity in the practices depending on the local context (size of the city, historical relations with the municipality, ...).

The result shows that there are a multiplicity of concerns related to energy consumption that are currently addressed but micro-climate is less taken into account. It has been pointed out the difficulty of data access and, when they exists, their unadapted spatial scale to perform territorial diagnostics. The weak use of Geographical Information Systems to cope with this issues was pointed out.

Concerning the expectations related to the MAPUCE project, agencies confirms the necessity of the climatic and energy consumption data from the project, but, they point out the importance to produce indicators applicable to all type of cases, from big to little cities, including rural or poor densely built territories. Needs on thematic training and generic tools are also often indicated.

The work on tools for transferring energy and climate data in a comprehensive way are currently underwork and will be nourished by the precedent results. Identification of the lacks of knowledge transfer related to climate and energy consumption as well as Environmental Urban Climate Maps will be produced. Methodological sheets and guides will be also produced. Feasibility of the proposed tools will be tested during the project over three terrains, Toulouse, LaRochelle and Aix-Marseille.

5. What next ?

The project started March 2014. It will last 3 more years.

After the completion of the urban database over French cities, simulations of energy and micro-climate will be done with the TEB model. The sociologists and lawyers of the project will analyze urban planning processes in Toulouse, La Rochelle & Marseille and propose ways to include quantitative data in legal documents '**at the right place, the right moment, with the right tool'.**

In terms of results, the cross-analysis of input urban parameters and urban micro-climate-energy simulated data will be available on-line as standardized maps for each of the studied cities. The urban parameter production tool as well as the models will be available as open-source. The fine data obtained within the project can also be used within the frame of the WUDAPT initiative (Mills et al, 2015, See et al 2015, this conference). On the one hand, it can be used to validate WUDAPT products, that are produced at larger scale and with much less input information. On the other hand, the LCZ and associated urban (and social!) indicators may be integrated within the WUDAPT database.

Acknowledgment

The MAPUCE project is funded by the Agence National de La Recherche, under grant *ANR-13-VBDU-0004.*

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