EPICEA PROJECT [2008-2010] MULTIDISCIPLINARY STUDY OF THE IMPACTS OF CLIMATE CHANGE ON THE SCALE OF PARIS

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Abstract

The EPICEA project is a joint collaboration between the City of Paris, the French Meteorological Office and the National Research Centre in Building to quantify the impact of climate change on Paris and the influence of building on urban climate and on adaptation strategy. First goal is to evaluate the evolution of the urban climate of Paris and its area with regard to climate change. Second goal is to realise a sharp analysis of the 2003 heat-wave over Paris with simulations using a database of the Parisian urban cover. The ultimate goal is to assess the climatic impacts during heat-wave periods that could result of actions on urban parameters. This information will allow the mapping of heat-wave vulnerability.

Key words: urban climate, climate change, built environment.

1. INTRODUCTION

The EPICEA project is a joint collaboration between the City of Paris, the French Meteorological Office (Meteo-France) and the National Research Centre in Building (CSTB). It extends over 3 years (2008 and 2010) and results are expected by the end of 2010. This project aims to quantify the impact of climate change on the city of Paris and the influence of building on urban climate and on adaptation strategy. It is divided into three parts :

- Evolution of urban climate of Paris and its area with regard to climate change,
- Focus on a particular event : sharp analysis of the summer 2003 heat-wave over Paris, and
- Link between urban built environment characteristics and urban climate

The ultimate goal is to assess the climatic impacts during heat-wave periods that could result of actions on urban parameters (geometry, radiative characteristics of surface,…). This information will allow the mapping of heat-wave vulnerability.

2. EVOLUTION OF URBAN CLIMATE OF PARIS AND ITS AREA WITH REGARD TO CLIMATE CHANGE

The goal of this first part is to evaluate the vulnerability of a big city like Paris to the evolution of its urban climate with regard to climate change. We compare present climatology to future climatology of Paris and its surroundings in order to quantify the evolution of Paris urban climate. Our methodology relies on simulations over long-time periods using a surface model with a specific urban surface scheme. The surface model is forced by meteorological conditions from an analyse system called SAFRAN (Durand et al., 1993), validated over France (Quintana Segui et al., 2007). It is a spatial and temporal interpolator which gives analysises of meteorological variables (temperature, humidity, wind, precipitation, pressure, and solar and atmospheric radiation) on a 8km*8km grid over France with an 1 hour resolution, using CORINE Land Cover (Heymann et al., 1993) and associated parameters from the ECOCLIMAP database. Our simulations are run on a 48km*48km grid with the city of Paris in its center, with a 1 km spatial resolution (Figure 1).

First serie of simulations covers the period 1970-2007 (01/08/1970 to 31/07/2007), as a reference of past/present climate of the city of Paris. Then, series of simulation of the future climate for the period 2046-2065 will be run with the French climate model from Meteo-France, ARPEGE-Climat. We will use emission scenarios produced by IPCC in its Special Report on Emission Scenarios (IPCC, 2007) : the A2 and A1B scenarios. Meteorological forcing for each scenario are issued from downscaling techniques used in the RExHySS project (http://www.sisyphe.upmc.fr/~agnes/rexhyss) :

- A first downscaling method based on weather types, developed at CERFACS (Boé et al., 2006). Weather types are defined on a known temporal period using meteorological fields at a local scale (using SAFRAN fields) and atmospheric circulation on a global scale (using ERA-40 reanalysis). Each simulated day in the future (by the global climate model ARPEGE-Climat) is then characterized by its corresponding weather type and associated to a reference day in the SAFRAN analysis thanks to its weather type and temperature and precipitation index. Final step consists of conditional resampling.

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- A second downscaling method based on statistical correction, developed at Meteo-France (Dequé, 2007).

For each scenario, three different simulations will be run : on the past/present climate 1970-2007, with comparison to our reference of past/present climate, on the future climate 2046-2065 with the downscaling method based on weather types, and on the future climate 2046-2065 with the downscaling method based on statistical correction.

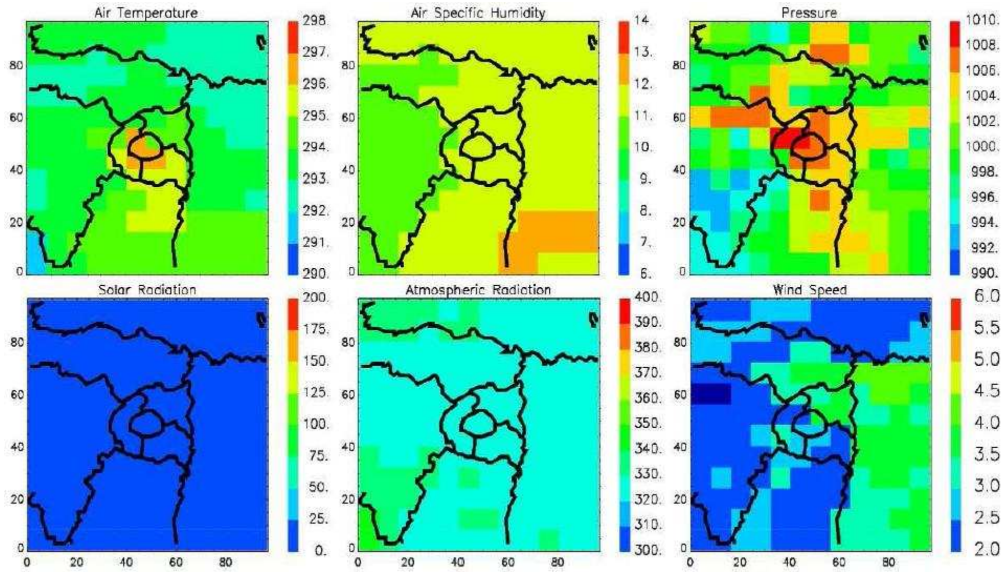

Figure 1 : Exemple of meteorological forcings from the SAFRAN system on the 8km*8km grid, with a temporal resolution of 1h and a 1km*1km spatial interpolation used in simulations.

Different physical and meteorological parameters will be analysed, including surface fluxes (Q*, Qh, Qe, Qg), surface temperatures, building internal temperature, temperature, humidity and wind in the canyon, temperature at 2m, and the anthropogenic heat flux.

These different simulations will allow us to understand the evolution of Paris urban climate between the 20th century and the mid 21st century, with an idea of the uncertainties given by the focus on two different scenarios and on two different methods.

3. SHARP ANALYSIS OF THE SUMMER 2003 HEAT-WAVE OVER PARIS

Projections of global climate change issued from the IPCC in 2007 (Pachaury et al., 2007) simulate an increase in frequency and activity of extreme heat-waves in the summer. That is to say, a phenomenon like the 2003 summer heat-wave may concern Western Europe on alternate summers as from 2050. Thus, it is necessary to focus on this phenomenon if one wants to extrapolate future climate, which is the aim of the second part of our study. This part consists in a sharp analysis of the 2003 summer heat-wave over the city of Paris. Simulations of the period from 08/08/2003 to 13/08/2003 (corresponding to the highest mortality) are conducted, using the atmospheric model Meso-NH (Lafore et al., 1998) and the specific urban scheme TEB, Town Energy Budget, (Masson, 2000).
The French Meso-NH atmospheric simulation system is a joint effort of the Centre National de Recherches Météorologiques and Laboratoire d'Aérologie which is designed as a research tool for small and meso-scale atmospheric processes. Dynamical part of the model is characterised by the non-hydrostatism hypothesis and the anelastic approximation. Physical part of the model consists in the parameterization of microphysics, convection, turbulence, radiation and surface. Surface treatment is externalised and specific surface schemes are coupling to the atmospheric model (TEB scheme for the city (Masson, 2000), ISBA scheme for the vegetation (Noilhan et Planton, 1989), and two other specific schemes for lakes, see and oceans).

The TEB scheme is built following the canyon approach, generalized in order to represent larger horizontal scales. Due to the complex shape of the city surface, the urban energy budget is split into different parts : three surface energy budgets are considered : one for the roofs, roads, and walls. Orientation effects are averaged for roads and walls. The TEB model is aimed to parameterize town-atmosphere dynamic and thermodynamic interactions and to simulate the turbulent fluxes into the atmosphere at the surface of a mesoscale atmospheric model covered by buildings, roads, or any artificial material. The latent and sensible heat fluxes, upward radiative fluxes and component momentum fluxes are calculated.

Our simulation relies on two configurations : the first one represents Paris as a uniform city with a 2km resolution and the second one represents Paris as a realistic city with a 250m high resolution, using datas from the Parisian Urbanism Workshop (APUR). Results of the first part of the simulation with the uniform enable us to make the energy balance, and to identify specific processes to the urban climate. The heat storage flux is also analysed and it shows an important diurnal cycle with positive values during the day (heat storage) and negative values during the night (heat release). Specific processes of the urban climate are simulated during summer 2003 heat-wave :

- The urban heat island (UHI) : the temperature in the urban area is higher than in the rural area, especially in the night ((Figure 2a),
- The urban boundary layer has a specific structure as the mixing over the city is much important than over the land especially during the day where the urban boundary layer is much higher, a specific circulation occur over the city with the urban breeze,
- The urban plume resulting from the combination of higher temperatures over the city and the synoptical wind, as for instance the urban plume simulated the 9th August 2003 at 18 UTC (Figure 2b).

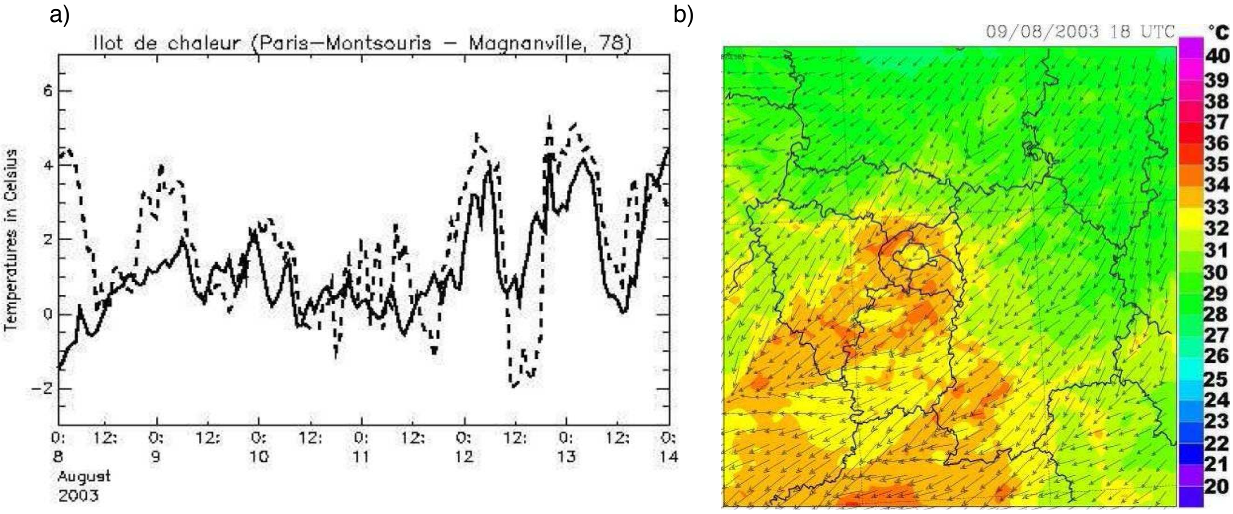

Figure 2 : a) Simulation of the UHI, based on differences between Paris and Magnanville (dotted line for observations and solid line for simulations). b) Superposition of temperatures at 2m and wind at 60m the 9th August 2003 at 18 UTC.

The second configuration of our simulation rely on a specifical database from APUR representing the Parisian urban cover with a 250m resolution. For each gridpoint we detail the surface of vegetation (figure 3), the surface of water, the surface and type of roof (zinc, claytiles, slates, flat roof), the surface and type of wall, the surface and type of road, the mean building height, the altitude, the built part and the building factor. These datas are integrated in the surface scheme to run the simulation.

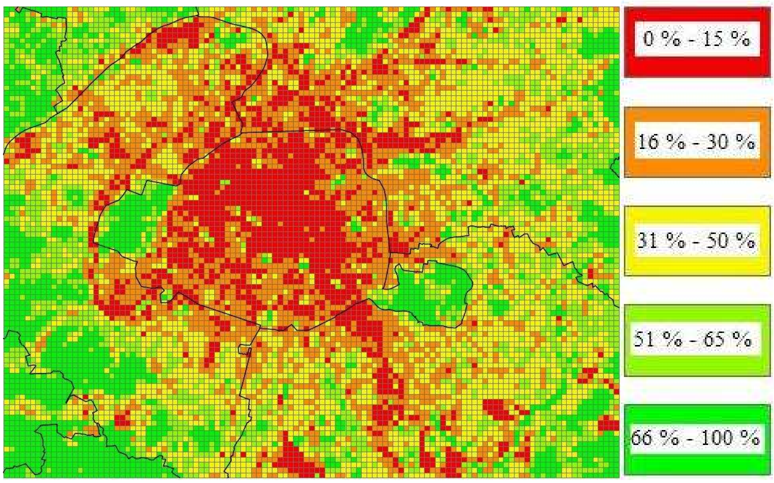

Figure 3 : Illustration of the Paris urban tissue representation : percentage of green surface in each 250m x 250m grid cell (Source: APUR).

4. LINK BETWEEN URBAN BUILT ENVIRONMENT CHARACTERISTICS AND URBAN CLIMATE

The third phase of the project concerns the impact on urban climate of modifications of the urban tissue. The aim is to assess the potential urban climate impact of actions on the built environment. Preliminary studies were carried out using the TEB pattern in "forced" mode during selected summer and winter days (Colombert, 2008). These results confirm the importance of radiative characteristics of material surfaces on the global energy balance. Future work will consist in evaluating the influence of urban parameters on urban climate over during the 2003 heat-wave. Construction materials characteristics, vegetation of urban space and anthropogenic heat sources will be taken into account. The modification of the urban geometry, which is relatively stable in Paris, will not be considered. The urban climate simulations will be carried out using the TEB pattern with the 250m*250m grid used in part II. Some contrasted scenarios will be considered as regard to the range of material characteristics. The values will be chosen in agreement with available construction technologies.
The comparison between these scenarios will provide indication on potential variation of temperature profiles over the Paris city. These results will be used to start developing a relation between mortality indicators (resulting from the extra-mortality observation during the 2003 heat wave measured by the Monitoring Health Institute (InVS, 2004) and the National Institute of Health and Medical Research) and modification of the urban built environment. The combination of such indicators is expected to contribute to the assessment of the vulnerability of a dense urban environment during a heat-wave event through the use of a GIS (Figure 4).

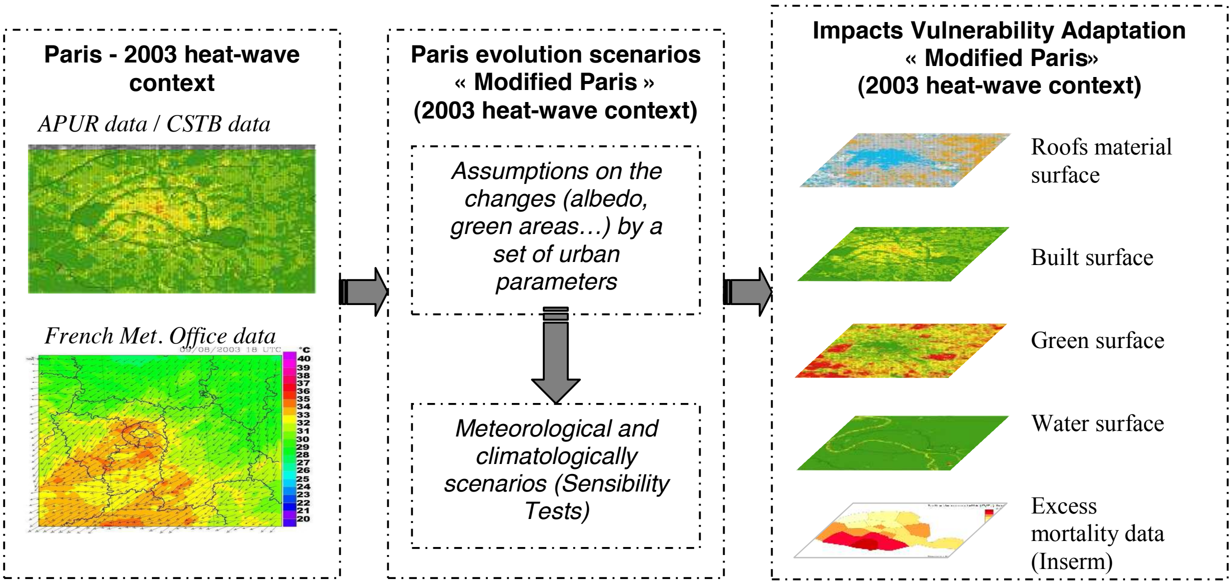

Figure 4 : Schematic representation of a modeling approach of the 2003 heat-wave in Paris as well as of impact studies and vulnerability indicators.

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