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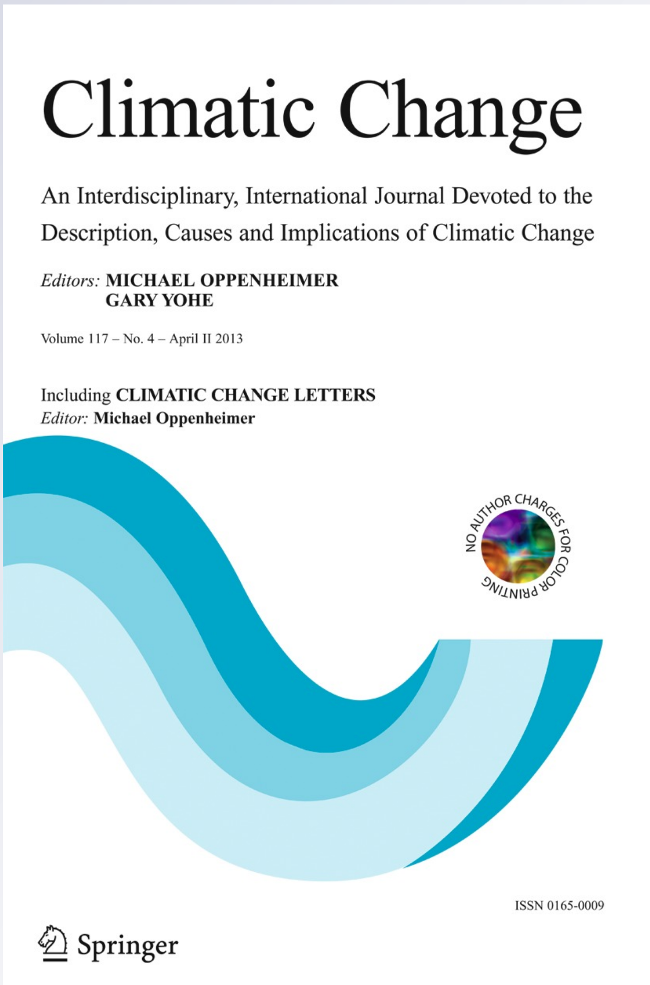

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“Grand Paris”: regional landscape change to adapt city to climate warming

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Abstract “Grand Paris” is a study carried out by ten teams of researchers and city planners in the aim of putting forward general guidelines for Paris urban area’s evolution by 2030. All the teams suggest making the area “greener” in some way, to combat climate warming by CO_2 sequestration. Our team also shows that extending the nearby forests by 30 %, favouring short farm-to-consumer circuits and using lighter coloured building materials will decrease the urban heat island, reducing the mortality during heat waves as well as the need for air-conditioning. These results lead us to reverse the way of thinking urban planning: the geographic and natural aspects should replace the urban infrastructure as a driver for planning urban development. This new strategy allows city changes on quite a large scale, that will have a favourable impact in terms of economics, leisure activities, greenhouse gas emissions and the local microclimate.

1 Introduction

The goal of this interdisciplinary study is to show how city planning changes, wide-reaching and realistic, can be thought out in advance to respond to a variety of aims: landscape, environment for daily life, creation of new economic activities, attenuation of and adaptation to climate change.

Such interdisciplinary cooperation is a challenge: not only are the themes considered very diverse but, above all, the scales to be tackled are not at all the usual ones. Architects work at the scale of a building and its immediate surroundings. City planners work on a district or the setting up of a public transport route. But encompassing a whole metropolis—that already exists and carries all its history with it—is something quite new. Posing the question in

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connection with climate change is even newer: Indeed, will it be possible, on the scale of a human lifetime, to have an effect on the climate via city planning?

2 The Paris metropolitan area

2.1 Context, expectations

Among world class cities, Paris holds a respectable rank. The "urban region" scale seems to be the most appropriate for an overall approach to the urban issues faced by Paris, as shown by the examples of other European metropolises like Berlin (Groß-Berlin) and London (Greater London). In 2008, the French Ministry of culture launched the "Grand Paris" consultation. Ten interdisciplinary teams, each bringing together architects, city planners, engineers and researchers, responded and made urban planning propositions. The Descartes group, led by the architect and urban planner Yves Lion, is one of the ten interdisciplinary teams, and was initially specifically built for this consultation. The authors all participated to the Descartes group. The objective of the "Grand Paris" is to propose general guidelines for Paris metropolitan area evolution by 2030.

The aim is no longer to urbanize but to humanize, no longer to lay out boulevards and build fortifications but to think about a complex, multiple, living, evolving entity. Its complexity must be apprehended from the point of view of sustainable development, the priority for the future.

2.2 Paris

Paris is a capital founded on a situation rather than on an exceptional site. It has no sea, no mountains, no strong topographical contrasts, but a river flowing through rich farmland and forests (Fig. 1). The landscape analysis performed by the Descartes group (Fig. 2) describes how Paris, in its double ring—non continous at present—of forests is interwoven with 6 rural regions having their own typical landscapes. The urban tissue began to grow up on these broad geographical features, followed by the star-shaped network of Haussmann's boulevards (19th century) that gave Paris its specific, complex and segmented character. The Paris metropolitan area developed later, particularly during the period of strong economic growth after the Second World War (1945–1973), when certain undertakings (wholesale market, facilities, large building projects, …) were moved out of the capital and new forms of rapid transport were set up: airports, suburban railways and the high speed train.

The urban area of Paris is home to a population of 11 million at present. Two million people live in the city itself and 9 million are spread over the 1,500 towns and villages that make up the suburbs. However, the 1,500 or so mayors lack the authority (of population or political influence) to be able to take any real initiatives (Gilli and Offner 2009). The policy of forming an integrated metropolis, inaugurated as early as the end of the 19th century by Greater London and the New York metropolitan area, and followed by Groß-Berlin in the early 20th century, has not been assimilated by Paris.

Conceiving the metropolis of the 21st century is already an extremely difficult task in itself. Applying these ideas to the Paris urban area is another sizeable challenge. Putting life back into the city centre, bringing people back into the heart of the capital will be nothing short of the architectural and town planning revolution of the 21st century!

Fig. 1 Paris geographical situation. Paris has built up on the plain, growing outwards from the River Seine **a** Paris and surrounding plains and forests (in background), **b** River development, **c** area of individual houses typical of the inner suburbs

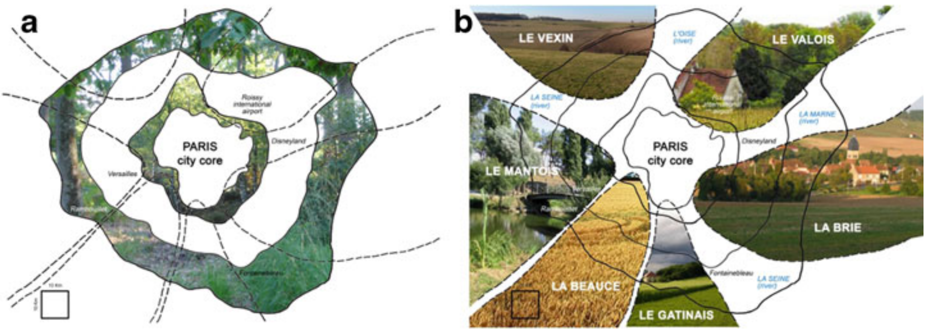

Fig. 2 Landscape analysis of the Paris region. **a** double ring of forest. **b** the 6 agricultural zones forming the basis of the future agricultural parks

2.3 Descartes group's proposal

With the ambition to improve the ordinary daily life of the people of the Paris metropolitan area, based on certain theoretical investigations that have already been undertaken, such as the studies on the dynamics of global cities (Sassen 1991) and the future of urbanized areas (Sieverts 2003), the Descartes group makes the proposal to rethink the relationship between city and country, re-planning the overall urban landscape—tackling economic objectives and leisure activities together—while continuing to adapt the city and suburbs to climate change.

3 Landscape and society; the forest-water-agriculture triplet

3.1 Limiting urban sprawl and rethinking the city's outskirts through their environment

The landscape is our common property and everyone should be able to enjoy it. By bringing people to recognize the environmental, cultural, landscape and recreational value of their land, we enable them to know it better, ensure that they respect it and encourage them to share it. In addition, developing forest and farmland areas at the edges of urban development will be an effective strategy for limiting sprawl.

3.2 Towards local farming

Farmland is generally under threat through being considered as a reserve of land that could be used for other purposes. It is possible to promote local farming. The city of Barcelona, for example, has possessed an agricultural park since 1998. Llobregat park is situated 7 km from the centre of the metropolis and serves as the lungs of the city, lungs that are active, productive and evolving (Paül 2004; Paül and Tonts 2005). It provides certified farm produce that takes advantage of the proximity of the city. Other agricultural parks have been created in large metropolises (Milan in Italy, Oita in Japan, and the Bois-De-La-Roche agricultural park in Montreal).

Food is an important element in a sustainable environment (Tukker et al. 2010). Reducing "food miles" helps to reduce a city's energy footprint (Lang and Heasman 2004), even though the production methods (Weber and Matthews 2008) and the type of local distribution (Coley et al. 2009) also have to be taken into account. The close links with farming inherent in the French way of life (Pettinger et al. 2008), French people's habit of buying (at least part of) their food in open markets and the special attention they pay to food quality (Gibney et al. 1997; Mennell 1996) all contribute to the development of local farming that respects a better environment (Lamine 2005; Brown et al. 2009). A consumer in the Paris region who buys using box schemes his fresh food, such as fruit, vegetables, cheese, meat and cereals, needs a farming area of 250 m^2 on average (value obtained from box scheme communities associations data analysis). Thus, at least 3,000 km^2 would be necessary if the present population of the city and suburbs were all to become "locavores" (an expression coined by J. Prentice).

We propose the creation of 6 agricultural parks connected with the various areas converging on Paris (brought out by the landscape analysis, see Fig. 2), each keeping its own agricultural specificities. Situated within about 60 km around Paris, the farms cover an overall area of 4,000 km^2. The objective of agricultural parks is to promote and organize local farming, as a complement to the current intensive cereal growing, so that the metropolis can be supplied with fresh produce grown locally. More than 80 % of this grain production is exported (Billen et al. 2012), thus part of the land dedicated to grain production could be used for local vegetable production without consequence on the grain supply of Paris. Fruit and vegetable production could be relocated within 100 km or less from Paris, as it was in the late 19th century (Billen et al. 2012). In addition, this would reduce transport distance and associated CO_2 emissions. Furthermore, grain production use an intensive application of synthetic fertilisers (that makes this agricultural industry a strong N_2O emitter, Schulze et al. 2009), and to promote local mix cropping farming would reduce the greenhouse gases emissions.

The agricultural countryside becomes a social space. The limits are clear. The question of city density can then be thought about more serenely.

3.3 Living forests

Global warming is "very probably" due to greenhouse gas emissions related to human activities (IPCC/WG1 2007; Meinshausen et al. 2009). Forests have a high capacity to absorb the CO_2 and other greenhouse gases in the atmosphere (−74 g carbon equivalent/m2/year for European forests (Ciais et al. 2008)). As Paris is in a temperate climate zone, its forests have the advantages of both freely available water and a long growing season (Janssens et al. 2005). They can thus grow rapidly and act as effective carbon sinks.

We propose planting 30 % more forests. The forests of the Paris region cover about 4,500 km^2 today (i.e. 22 % of the overall surface area). They are mature forests that are hardly exploited and not very productive. The additional 1,400 km^2 would be planted on reconverted farmland (financial subsidies to be set up). The new forests would be established so as to encourage a green network to grow back again, linking the existing forest areas together. These woodlands would thus partly form a forest belt around Paris and its suburbs whilst interweaving and interacting with the built-up areas. Figure 3a shows the present state of forests in Paris region, and Fig. 3e shows the proposed extension and densification of forests: densification of forests in the west, and links between large existing forests in the east and south-east. This would create giant "environmental corridors" stretching over tens of kilometres, at the scale of the whole region.

Moreover, in contrast to the present situation, all the forests could be exploited. Half of the available wood (i.e. 375,000 t/yr) could be mobilized in the medium to long term to produce wood for building or heating (assuming that new sectors of the economy are opened up together with the appropriate know-how). Agroforestry can also provide a means of favouring short distribution circuits. Both of these strategies for exploiting the forest, although they may limit CO_2 sequestration in the short term, are very effective in attenuating climate change in the long term by taking the place of fossil fuels or materials requiring more energy for their production (IPCC/WG3 2007; Sims et al. 2006). Finally, having leisure activities in the nearby forests would limit the distance covered by city-dwellers, who often travel far at the weekend (Orfeuil and Soleyret 2003). For this, city planners must think of facilitating access to the forests (old or to be planted) by public transport.

3.4 Free access to water

The Paris region is watered by a large river and several tributaries that have shaped its site and its towns. However, in the second half of the 20th century, urbanization gradually detached itself from the rivers, either by ignoring them or by investing in new sites far from the water courses. It is now a question of letting water regain the place it used to hold in the

Fig. 3 "Grand Paris" scenario. The present Paris urban area (**a**,**b**,**c**,**d**) and the scenario proposed by the Descartes team (**e**,**f**,**g**,**h**) (from top to bottom: overview, crops, forests, lakes)

Paris metropolitan area, while reducing the vulnerability of the various spaces to the risks induced by this highly capricious element.

Increasing the area of water bodies (by 300 km^2) has several aims: (i) to help to protect against flooding, (ii) to build reservoirs of biodiversity, (iii) to ensure sufficient water resources for agriculture (including the new fruit and vegetable production), and (iv) to develop local leisure and tourism areas for the population.

Water quality in general is an issue, either linked to combined-sewage-overflows, ordinary runoff (washing pollutants from roads or roofs), limited water resource or appearance of new types of pollution (subject to the new REACH European Regulation on chemicals).

Improving water quality in the whole metropolitan area will mean restoring the urban water cycle, limiting run-off, and encouraging infiltration and evaporation. The Australian concept of “Water Sensitive Urban Design” (Fletcher et al. 2010) is a useful guide here. The banks of the rivers and the new wet areas will be accessible to the population. A variety of possibilities will be developed in these areas, such as walks, swimming, sailing, living spaces, … All the uses and functions of rivers can be integrated into an urban sustainable development project.

4 Large scale city planning as a lever for adapting to climate change

From considerations that firstly concerned social and city planning aspects, we have built up a global strategy for re-planning the landscape of the Paris region as a whole. This strategy also includes arrangements intended to reduce greenhouse gas emissions (forests, moving from intensive grain to local mixed cropping farming), so as to contribute to the attenuation of global warming.

Is it possible to kill two birds with one stone? Will this great landscape effectively improve the local urban climate of Greater Paris and the comfort of the people who live there?

4.1 Heat-waves, urban heat island and urban vegetation

Citys are often hotter than the surrounding countryside. This effect is known as the Urban Heat Island (Oke 1982) and was first demonstrated for London by Luke Howard (1818) (Mills 2008). A heat island forms when weather conditions are favourable: sunny days followed by clear nights and little air movement. In fact, the night-time heat island is created during the day. In the country, the energy coming from the sun is partly used to evaporate the ground water sucked up by plants through their roots (Grimmond and Oke 1991; Changming et al. 2002). The vegetation itself thus stays cool. In contrast, materials present in the city—bricks, concrete, asphalt, tiles, etc.—heat up a lot during the day (particularly if they are dark in colour) and act as heat stores. When night falls, the countryside cools quickly by radiating heat directly to the sky. Urban surfaces cool more slowly: whereas they have already accumulated more heat, they lose less energy by radiation (the “canyon” shape of streets makes them into “radiation traps”, the heat radiated being in part intercepted and kept by the urban fabric). This effect is particularly large in dense European cities. Thus the air cools more slowly in the city.

The combination of climate warming (3–6° in summer for Paris in 2100 depending on the emission scenario, Jacob et al. 2007) and the urban heat island (that can reach 8–10° at night for a city the size of Paris) would lead to very high temperatures in the city. Heat-waves like that of 2003 in Europe would become common: in the A2 emission scenario, with an average of 30 days of heat-wave conditions in the north of France (Déqué 2007). Limiting the consequences of such heat-waves is a major health challenge (Scott et al. 2004): 8,000 deaths were attributed to the 2003 heat-wave in the Paris urban area (Fouillet et al. 2006).

Bringing vegetation into the city is thus a possible path towards adapting towns and there are many ways of doing it: parks, trees in the streets, and vegetated roofs. Street trees seem to have their main cooling effect in the daytime (by providing shade) and the effect of a green roof (in isolation) on the air temperature is not certain: Bowler et al. (2010) review's states that observations of 125 parks show that the air is cooler in parks than in the neighbouring built-up areas both by day (0.94 °C) and by night (1.15 °C). However, few studies document the extent of the influence of parks. A park of about 150 ha can have an impact up to about a kilometre away in favourable conditions (Upmanis et al. 1998) but the influence of two smaller parks studied was less marked. Although there have been studies on the cooling impact of parks covering a few dozen hectares within the fabric of a city, no-one has assessed the influence that landscape developments of several thousand km^2, as envisaged here for Greater Paris, would have.

4.2 Numerical modelling shows "Grand Paris" decreases the urban heat island by 2–3 °C

We use here an original, comprehensive and physically-based numerical modelling framework (Fig. 4) to quantify the future impacts of the "Grand Paris" planning scenario. We are then able to show that the proposed landscape change (forests, local farming, water) coupled to reflective surface coverings reduces the Paris urban heat island by as much 2–3 °C.

Our numerical framework takes account of all the interactions between the rural and urban environments and the atmosphere. The heat-wave of 2003 is simulated by combining the chosen development scenarios (more details in Appendix), numerical models simulating exchanges of energy and water between the surfaces and the atmosphere (ISBA—Interaction between Soil Biosphere and Atmosphere—, for the vegetation, Noilhan and Planton 1989; TEB—Town Energy Balance—for the built-up areas, Masson 2000; Lemonsu et al. 2004), and a 500-m-resolution atmosphere model (MesoNH, Lafore et al. 1998). Both surface models take the key processes into consideration (solar and thermal radiation, heating of the air, evaporation and transpiration of various plants for ISBA, 3D shapes of buildings and radiation trapping for TEB, effects of urban materials). The impacts of the proposed planning changes are

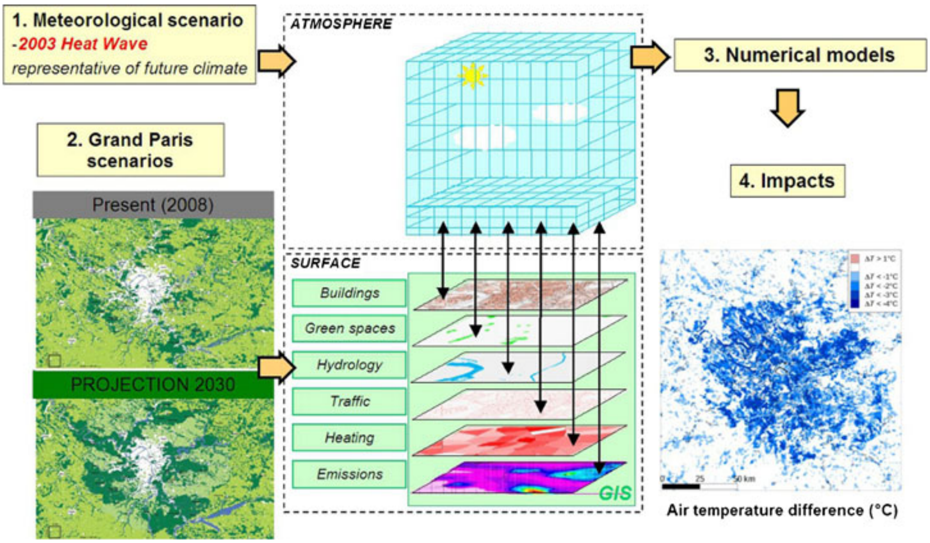

Fig. 4 Methodology developed for the study of "Grand Paris"

deduced by comparing the simulation for present-day Paris with that for the future Grand Paris.

In the daytime, the impacts on the air temperature simulated by the models are relatively localized (Fig. 5a) and directly related to the underlying change: the temperature is considerably lower over lakes but the cooling does not spread beyond them. The temperature in the city falls by about 1 °C, thanks to the application of the white paint and the cool roofs on the buildings in the suburban area.

At night, the urban heat island reaches about 7 °C, with temperatures of 31 °C in the centre of Paris. Light coloured buildings also decrease night-time temperature by up to 1 °C (Fig. 6), while landscape changes have an even larger effect (2 °C, Fig. 7). Then, the proposed combined strategy reduces the heat island considerably (Fig. 5b): although the lakes do not seem to influence night-time temperature on the urban-area scale, the strategies of reafforestation and changing farming practices, combined with lighter coloured buildings, lower the night-time temperature by 2–3 °C throughout the suburban area, and by 1–2 °C in the historic centre of Paris even though no changes are made there. This can be explained by the fact that the air was cooler over most of the urban area and the night breezes brought this cooler air into the centre of the capital.

So the large-scale planning of a metropolis, taking not only built up or building land into consideration but also farmed land and natural spaces around the metropolis serves as a lever for both combating and adapting to climate change. Looking far in time also makes it necessary to look far in space—beyond the suburbs and even the urban fringe.

5 Conclusion

The Descartes group has drawn up an overall strategy for acting on the potential effects of climate warming, from the standpoint of both adaptation and attenuation. Through re-inventing the landscape, we see a new relationship growing up between the city and the natural world, where the surrounding countryside can no longer be considered as a space for the expansion of the city. Short distribution circuits require the development of farming near where the population lives and sustainable exploitation of the forests.

Adaptation rhymes with attenuation of climate change impacts. Reaching the optimal urban system requires a combined application of both approaches at all levels of the urban project. In this study, numerical modelling has provided an original, comprehensive and physically-based framework to assess and quantify the impacts of different planning options.

It is now up to the operational participants: city planners, politicians and local authorities, to use these ideas to best advantage. Such measures cannot be put into operation instantaneously but their cost, at least in Europe, could be limited—or even cancel itself out—as it would be covered by a gradual transfer of (existing) farming subsidies from one sector of agriculture to another.

All this induces a "reversal of our point of view". Up to the end of the 20th century, cities were designed mainly through their main driver: infrastructure. Now, most of the infrastructure is in place and the city planning approach of this early 21st century is seeking to harness a new driving force, sustainable development. We are now turning our attention to the geographic and natural aspects, inside and even more outside the city, and to the living environment. Working on the city-climate combination leads to a new way of designing the city.

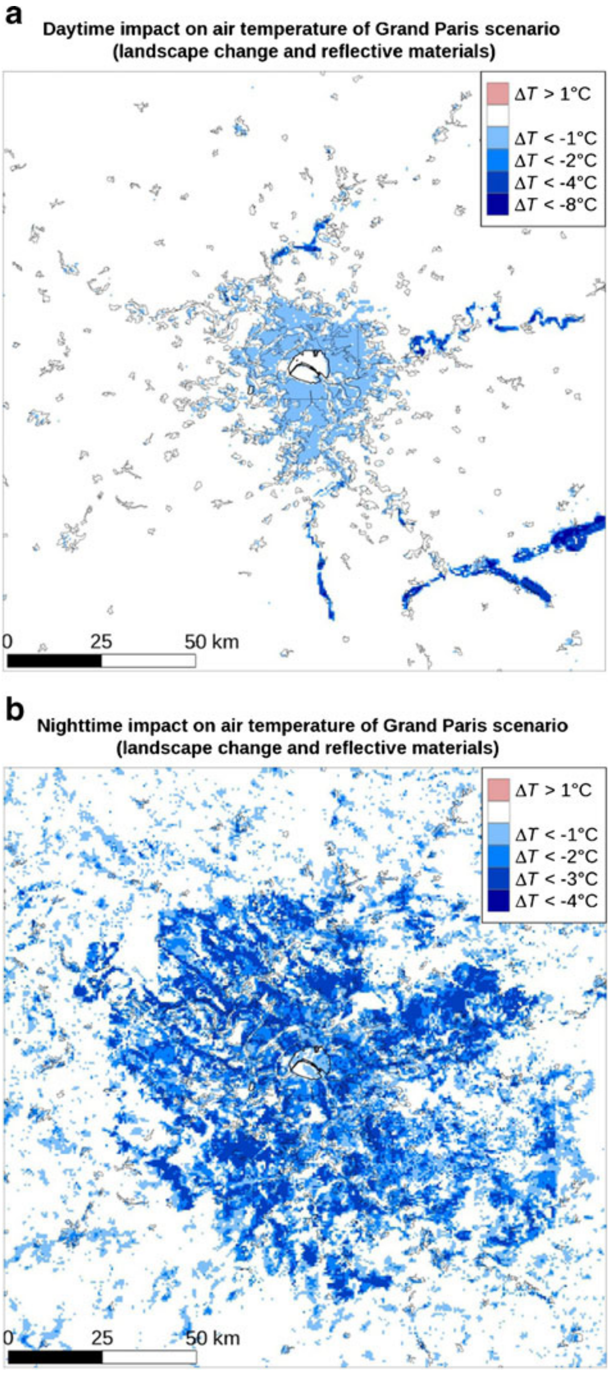

Fig. 5 Impact of "Grand Paris" scenario. Impact on mean temperatures for strong heat wave event in daytime (12 h–16 h, **a**) and at night (3 h–7 h, **b**). Urbanized areas are displayed as *dark lines*. Temperatures difference (ΔT) (at 95 % confidence level) between 2030 Grand Paris scenario and present Paris are in *color*

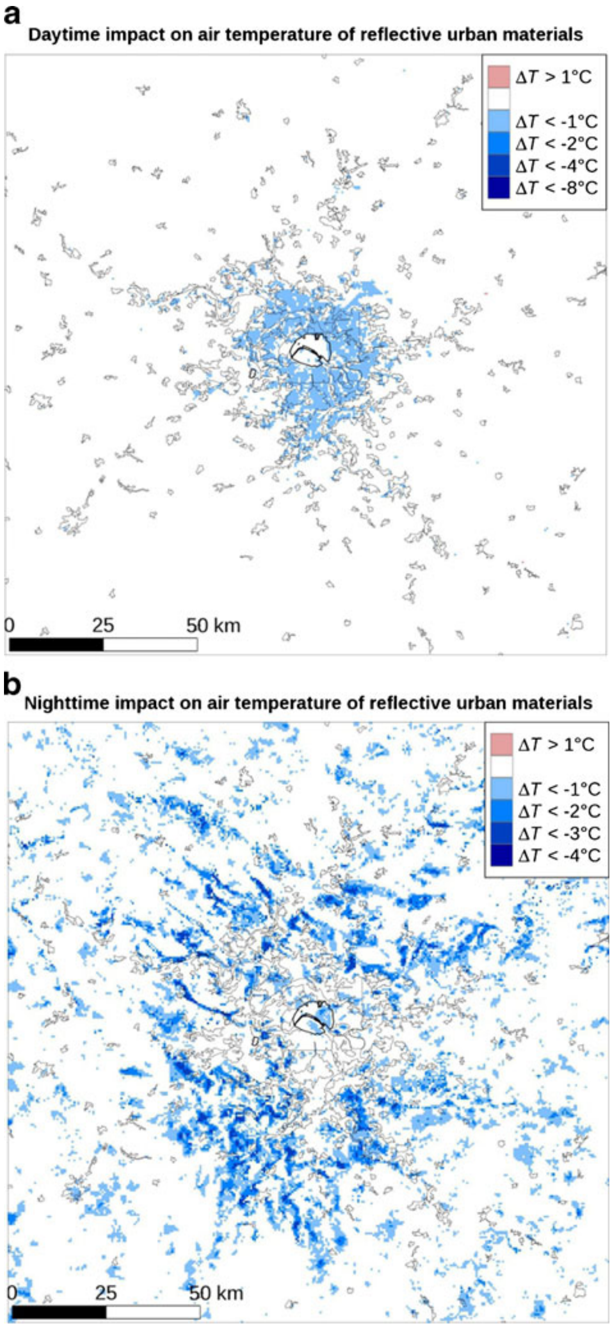

Fig. 6 Impact of light colored buildings scenario alone. Impact on mean temperatures for strong heat wave event in daytime (12 h–16 h, **a**) and at night (3 h–7 h, **b**). Urbanized areas are displayed as *dark lines*. Temperatures difference (ΔT) (at 95 % confidence level) between 2030 Grand Paris scenario and present Paris are in *color*

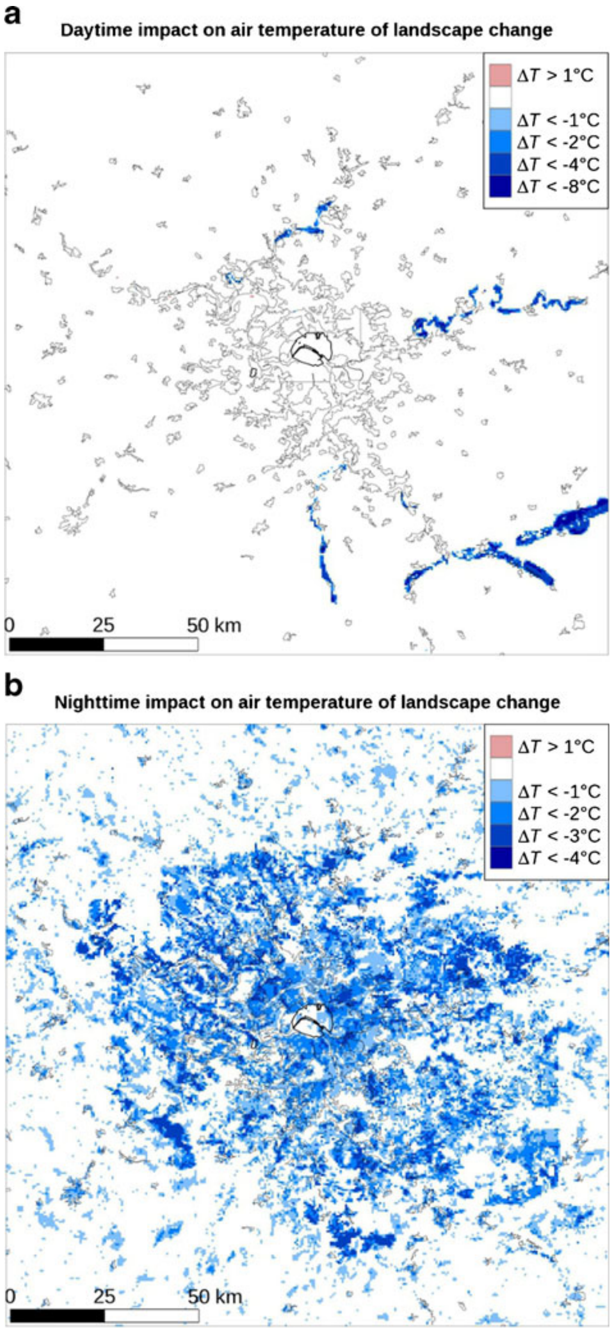

Fig. 7 Impact of landscape urban planning scenario alone. Impact on mean temperatures for strong heat wave event in daytime (12 h–16 h, **a**) and at night (3 h–7 h, **b**). Urbanized areas are displayed as *dark lines*. Temperatures difference (ΔT) (at 95 % confidence level) between 2030 Grand Paris scenario and present Paris are in *color*

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Appendix: Description of "Grand Paris" scenario in the model

Simulations are performed for Paris present area and for the proposed development scenario, which has two facets:

1) city-planning: the broad landscape change.

1,400 km^2 of forests are created and 300 km^2 of wet areas are added. 4,000 km^2 of wheat fields out of the existing 11,500 km^2 (most widespread crop in the Paris region) are turned over to fruit and vegetables. As August 2003 was also a period of drought, the humidity of the soil is low, set to 10 % in the simulations (from the estimate given by the operational weather forecasting models). In addition, the wheat had already been harvested and so no longer gave rise to evaporation (FAO 1998). Fruit and vegetables are summer crops and therefore were still green: 1.5 m^2 of leaf per m^2 of ground area. This value is low (in a normal year it would be 3 or 4 m^2) but yields a small amount of evaporation by these crops.

2) technological aspect: use of reflecting surface coverings

The traditional housing in countries around the Mediterranean (Greece, Spain, North Africa), which all have hot, dry climates, is composed of whitewashed houses. Much of the energy from the sun is thus reflected back into space, which limits heating (Synnefa et al. 2008). In the framework of climate change, we decided to test a similar strategy for «Grand Paris». In the suburban areas around the old heart of Paris, reflecting paint was applied: white roofs, also known as cool roofs (reflecting 80 % of the sunlight instead of 15 %), lighter coloured walls and roads (45 % reflection instead of 25 % for the walls, 30 % instead of 8 % for the roads).

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