

Contents

INTRODUCTION	
PLANNING AND CLIMATE CHANGE: CONCEPTS, APPROACHES, DESIGN.	
PART I THE URBAN HEAT ISLAND – EVIDENCE, MEASURES AND TOOLS	
CHAPTER 1 FORECASTING MODELS FOR URBAN WARMING IN CLIMATE CHANGE.....	
1.1 <i>General Introduction</i>	
1.2 <i>Overview of models and tools</i>	
1.3 <i>Case studies</i>	
1.3.1 Projections of climate trends for urban areas in Central Europe using WRF	
A) Introduction.....	
B) Data and methods	
C) Results	
D) Conclusion	
1.3.2 Human-biometeorological assessment of changing conditions in the region of Stuttgart in the 21st century	
A) Data and Methods.....	
References.....	
1.3.3 Urban climate modelling with SURFEX/TEB at the Hungarian Meteorological Service	
A) Introduction.....	
B) Methodology	
C) Results	
Budapest	
Szeged	
D) Summary	
References.....	
1.3.4 Regional climate modelling considering the effect of urbanization on climate change in Central Europe	

A) Introduction.....	.....
B) BACKGROUND OF MODELLING FOR EUROPE.....	.....
C) URBAN PARAMETERIZATION AND EXPERIMENTAL SETUP .....	.....
D) RESULTS.....	.....
E) SUMMARY .....	.....
References.....	.....
1.3.5 Statistical downscaling techniques applied to ENSEMBLES GCMs: Bologna-Modena case study .....	.....
A) Introduction.....	.....
B) Data and Methods.....	.....
C) Results .....	.....
D) Conclusion .....	.....
Acknowledgement .....	.....
References.....	.....

CHAPTER 2 ASSESSMENT INDICATION AND GOLD STANDARD.....

INTRODUCTION .....	.....
2.1 <i>Concepts</i>.....	.....
2.2 Planning a Representative Urban Climate Station Network	
2.3 Exposure of instruments .....	.....
Temperature .....	.....
Humidity.....	.....
Wind speed and direction .....	.....
Precipitation .....	.....
Solar radiation .....	.....
2.4 Measurement programs in urban environments.....	.....
2.5 Site description for METADATA.....	.....
2.6 Data transmission and data management .....	.....
2.7 SHORT DESCRIPTION OF THE WEB DATABASE AND UHI ATLAS ELABORATION	
2.7.1 <i>UHI Atlas and database</i> .....	.....
2.7.2 Large scale data (<0,5 km resolution) .....	.....
2.7.2.1 Corine Land Cover .....	.....
2.7.2.2 Land Cover/Land use for cities included in project (Urban Atlas) .....	.....
2.7.2.3 Landsat TM, ETM images (thermal band etc.).....	.....

2.7.2.4 SRTM 90m Digital Elevation Data (DEM)	
2.8 SMALL SCALE DATA ($\geq 0,5$ KM RESOLUTION).....	
2.8.1 MODIS NDVI images - Aqua & Terra (MYD13A2 & MOD13A2).....	
2.8.2 MODIS LST images - Aqua & Terra (MYD11A2 & MOD11A2).....	
Short description of MODIS NDVI images	2.8.3 VIIRS night scene images
Short description of VIIRS (Visible Infrared Imaging Radiometer Suite)	
2.8.4 Air temperature (2 m above the ground).....	
Short description of Air temperature data	
2.9 The data from the partners.....	
2.9.1 The case of Bologna and Modena	
2.9.2 The case of Stuttgart	
2.9.3 The case of Warszaw	
2.9.4 The case of Prague	
2.9.5 The case of Budapest	
2.10 Other data	
2.10.1 UHI Project Partners.....	
2.11 SUMMARY.....	
CHAPTER 3 METHODOLOGIES FOR UHI ANALYSIS	
INTRODUCTION	
3.1 <i>The Urban heat island in central Europe</i>	
3.2 <i>Short-term analyses of the observations</i>	
3.3 <i>Long-term analyses of the observations</i>	
3.4 <i>Modelling efforts</i>	
3.5 <i>A Systematic framework for the representation of urban variables</i>	
3.6 <i>Conclusion</i>	
3.7 RELEVANCE OF THERMAL INDICES FOR THE ASSESSMENT OF THE URBAN HEAT ISLAND.....	
3.7.1 Methods and data	
Physiologically Equivalent Temperature	
Universal Thermal Climate Index	

3.7.2 Exemplary results	
3.7.3 Discussion and conclusion	

CHAPTER 4 DECISION SUPPORT SYSTEMS FOR URBAN PLANNING .

4.1 Introduction.....	
4.2 Development Of The Uhi Project’s DSS.....	
4.3 UHI’s Decision Support System	
4.3.1 Structure.....	
4.3.2 The interface	
4.3.3 Project Logical framework.....	
4.3.4 The Consultation Tool	
4.3.5 The DSS.....	
4.4 DSS Input	
4.4.1 WP3	
4.4.2 WP4	
4.4.3 WP5 Mitigation and adaptation strategies	
4.5 Main acronyms.....	

PART II PILOT ACTIONS IN EUROPEAN CITIES

CHAPTER 5 COUNTERACTING URBAN HEAT ISLANDS: SOLUTIONS FOR EUROPEAN CITIES.....

5.1. <i>Implementing solutions for climate change in urban context.....</i>	
5.2 <i>The Metropolitan Cluster Of Bologna-Modena</i>	
5.2.1 Urban and environmental framework.....	
5.2.2 Pilot area identification methodology and descriptio	
5.2.3 UHI phenomenon in the urban area of Modena and application of models to simulate mitigation measures	
5.2.4 Experimental environmental quality index to assess the UHI’s mitigation actions in a building lot	
5.2.5 Adaptation Strategy to Heat Risk: assessment of a possible development of the heat risk alert system based on the use of emergency ambulance data	
5.2.6 Conclusions.....	
<i>Next Steps.....</i>	
ANNEX A.....	

ANNEX B	
ANNEX C	
5.3 <i>The Urban Corridor of Venice And The Case Of Padua</i>	
5.3.1 Urban and environmental framework.....	
5.3.2 Pilot areas identification methodology	
5.3.3 UHI phenomena in the pilot area	
5.3.4 Feasibility study: UHI mitigation strategies by simulations	
5.3.5 MITIGATION OF AND ADAPTATION TO UHI PHENOMENA: THE PADUA CASE STUDY	
<i>Introduction</i>	
ANALYSIS METHODS: TRADITIONAL SURVEYS AND REMOTE SENSING.....	
FEASIBILITY STUDY	
THE PILOT AREA AS TESTING GROUND FOR THE VENETO REGION	
POSSIBLE TRANSFORMATIONS OF THE PILOT AREA.....	
<i>Outdoor public spaces</i>	
<i>Public green spaces: create new traffic islands and plant new trees</i>	
<i>Private Outdoor Spaces</i>	
<i>Post-scenario intervention</i>	
FOCUS A - ENERGY AND URBAN FORM	
FOCUS B - USING AERIAL PHOTOGRAMMETRY FOR URBAN SUSTAINABILITY ANALYSIS	
FOCUS C - URBAN SPRAWL AND MEASURES FOR ENVIRONMENTAL SUSTAINABILITY	
5.4 <i>Pilot action City of Vienna – UHI Strat Vienna</i>	
5.4.1 Introduction.....	
5.4.2 A consistent strategy for UHI in urban planning	
5.4.3 UHI and the urban climate in Vienna – status quo and future developments.....	
5.4.4 Fields of action for STRAT-UHI Vienna - city-wide actions and actions for individual lots and buildings	
5.4.5 Level of action – from master plan to project.....	
5.4.6 Feasibility studies	
5.4.7 Conclusion	
5.5 <i>Pilot actions in European cities - Stuttgart</i>	

5.5.1	The city of Stuttgart.....	.....
5.5.2	Pilot action study Stuttgart.....	.....
5.5.3	Transferring the findings of the pilot action study to urban planning process in Stuttgart .....	.....
5.5.4	Stuttgart's heat warning system HITWIS.....	.....
5.6	<i>Urban Heat Island and bioclimatic comfort in Warsaw .....</i>	.....
5.6.1	Introduction - UHI as an effect of spatial organization of the city .....	.....
5.6.2	Pilot areas methodology .....	.....
5.6.3	Methods .....	.....
5.6.4	The role of urban vegetation in reduction of UHI – the results of microclimatic research .....	.....
5.6.5	Possibility of reducing UHI intensity.....	.....
5.6.6	Assessment of mitigation measures.....	.....
5.6.7	Adaptation strategies .....	.....
5.7	<i>Urban Heat Island In The Ljubljana City .....</i>	.....
5.7.1	Introduction.....	.....
5.7.3	Mitigation of the urban heat island in the Ljubljana city area .....	.....
5.7.4	Pilot actions .....	.....
5.7.5	Conclusions.....	.....
5.7.6	References.....	.....
5.8	<i>Pilot Action In Budapest .....</i>	.....
5.8.1	<i>Planning Framework .....</i>	.....
5.8.2	<i>The UHI Project and the Planning of the Pilot Area.....</i>	.....
5.8.3	<i>Description of the Pilot Area.....</i>	.....
5.8.4	<i>Methodology – the Tools.....</i>	.....
5.8.5	<i>Suggestions for Application of the Tools .....</i>	.....
5.8.6	<i>Effects of Interventions on the Local Climate .....</i>	.....
5.8.7	<i>Action Plan for Local Governments in Heatwave Alert Situations.....</i>	.....
5.9	<i>Pilot actions in European cities - Prague .....</i>	.....
5.9.1	<i>Urban and environmental framework.....</i>	.....
5.9.2	<i>Pilot areas identification methodology. ....</i>	.....
5.9.3	<i>UHI phenomena in the pilot area and connection with specific aspects of urban form and built environment .....</i>	.....

5.9.4. *General strategic vision to mitigate UHI effects-
Counteracting measures*

GLOSSARY AND ABBREVIATIONS

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Abstract

Urban heat island (UHI) is micro-climatic phenomenon which occurs within urban areas and consists of generally warmer temperature than rural surroundings. The current development of cities together with FORESEEN urban DEVELOPMENT make this phenomenon of fundamental importance also for stakeholders and urban planners.

The attention to these items is proved by the funding of the project “Development and application of mitigation and adaptation strategies and measures for counter-acting the global Urban Heat Islands phenomenon”.

The main objective of this project is to establish a trans-national attention for the prevention, adaptation and mitigation of the natural and anthropogenic risk arising from the urban heat island phenomenon. The partnership is basically twofold, with technical institutions as well as local stakeholders, both coming from each of the regions involved in the project.

The direct participation to the project of local stakeholders guarantees the possibility of an effective impact of UHI project objectives into planning strategies, with a specific emphasis on the human bio-meteorological factors that are relevant for the urban planning process.

Introduction

The term “heat island” describes a micro-climatic phenomenon that occurs in urban environments. It consists of a relevant increase of air temperature within urban areas which are thus generally warmer than the surrounding rural neighbourhoods. Usually, the temperature difference is more relevant during the night than during the day and it is most apparent when winds are weak.

At seasonal level, urban heat island phenomenon occurs in winter as well as in summer, when it is more severe for the population living in the urban environment. The UHI threat to human health within cities have to be carefully tackled: in fact, the high summer temperatures heavily affect the quality of life in the cities producing a lot of negative impacts that may be summarized as a relevant deterioration of human health with bioclimatic discomfort, as well as an increase in energy consumption (for example, because of the need of air conditioning) which in turn determines higher emission of air pollutants and greenhouse gases. These aspects make urban agglomerations increasingly vulnerable to climate change. Although UHI phenomenon is not a direct consequence of climate change, it is expected to exacerbate due to the predicted overall warming in the framework of climate change scenario for the second half of the century, when mean temperature are generally likely to increase.

UHI phenomenon has been shown to be directly linked with the size of urban areas and with population living inside. In this respect, it is likely to become more severe in the forthcoming years due to the constant growing of the number of people living in urban areas. In fact, global population is increasingly concentrating in cities: since 2007 more than a half of the human beings is living inside urban areas. In Europe, about 75% of people is currently living in urban areas, with a projected increase up to 80% in 2020. As for the whole globe, in 2050 the share of the urban population will reach almost 70% of the total, implying that about 6.3 billion people will live in urban areas.

There are a number of reasons why UHI phenomenon affects urban areas. The main cause is related to the physical characteristics of materials composing urban surfaces absorbing rather than reflecting solar radiation (concrete and asphalt among the others) so that the surplus heating of the surfaces determines the emission of a large amount of long-wave radiation, especially during the night. In addition, urban areas generally contains small portions of natural surfaces (vegetation in parks, gardens, etc.) which could contribute to maintain a stable energy balance.

A further factor related to the increase of temperature is the waste heat generated by energy consumption (heating and cooling plants, industrial activities, transports, etc.).

Our cities and urban areas in general are facing many challenges - economic, social, health and environmental. However, the proximity of people, business and services associated with cities also creates opportunities to improve resource efficiency. Indeed, well-designed and well-managed urban settings offer great opportunities for sustainable living; partnership and coordination from the local to the European level can support their improvement. Climate change has the potential to influence all the components in the urban environment and to raise new and complex challenges for the quality of life, health and human biodiversity inside urban areas. Poor urban design can worsen the impacts of climate change.

The attention of the European Union to the problems related to UHI is proved by the funding of the transnational cooperation project within the Central Europe Programme “Development and application of mitigation and adaptation strategies and measures for counteracting the global Urban Heat Islands phenomenon” (3CE292P3). This project is coordinated by the Regional Agency for Environmental Protection in Emilia-Romagna, Italy, and involves 17 partners within Central Europe area. The partnership is basically twofold, since it is characterized by the presence of technical institutions, as well as local stakeholders, both coming from each of the regions involved. Partners are listed in the following:

- Regional Agency for Environmental Protection (Arpa), Emilia-Romagna, Italy;
- Emilia-Romagna Region, General Directorate Territorial and Negotiate Planning, Agreements, Italy;
- Veneto Region, Spatial Planning, Italy;
- CORILA, Italy;
- Karlsruhe Institute of Technology (KIT); Germany;
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- Hungarian Meteorological Service, Hungary;
- Faculty of Mathematics and Physics , Charles University Prague, Czech Republic;
- City Development Authority of Prague, Czech Republic;
- Czech Hydrometeorological Institute, Czech Republic;
- Scientific Research Center of the Slovenian Academy of Sciences and Arts, Slovenia;
- Department of Environmental Protection, Municipality of Ljubljana, Slovenia.

The main objective of UHI project is to establish a trans-national attention for the prevention, adaptation and mitigation of the natural and anthropogenic risk arising from the urban heat island phenomenon. UHI project is organized through six Work Packages, namely:

1. Project management and coordination;
2. Communication, knowledge management and dissemination;
3. Framework analysis;
4. Transnational Network and UHI assessment's tools;
5. Mitigation and adaptation strategies;
6. Pilot and capitalization actions for limiting UHI's effect.

The first step consists in gaining a more detailed insight of the phenomenon and of potentially correlated risks, starting from a deep analysis of the current knowledge both from a scientific and a legislative point of view. In other words, to collect scientific planning and legislative experiences throughout Central Europe in order to influence some suitable and sustainable actions in urban land use. This state-of-the-art analysis is carried out with the traditional micro-meteorological techniques and is specifically designed to develop mitigation and adaptation as well as management strategies. UHI intensity has been measured within each of the main urban areas within Central Europe comparing meteorological data obtained in a monitoring station located inside cities with data obtained in a station located in the rural surroundings using a common methodology. In addition, a web atlas has been implemented, after the development of a GIS database where project partners uploaded meteorological and air-quality data, as well as maps of satellite images, soil use and DEM referring to the different areas involved in UHI-project.

Communication and dissemination within UHI project represent a very relevant aspect of the developed activities, with a sharing of the competence and experi-

ences not only in the framework of the partnership itself, but also with all the other European Institutions and stakeholders in general. Moreover, also people living in urban areas should be addressed by the communication and dissemination activities through the largest possible number of mass-media. Among the other dissemination activities, local events are worth of some words, since they are designed to facilitate the interaction between partners that are developing pilot activities and local stakeholders that can contribute to them. The necessary interaction in a trans-national network will then ensure a widespread audience for the dissemination and exploitation of methods and findings from the project activities. A number of local events have been organized by UHI project partners with a certain success in terms of participation and debate among the various subjects involved, not only related to the development of a trans-national debate on the UHI theme but also to the interactions with climate change.

Another important aspect is related to the elaboration of scenarios for UHI phenomenon taking into account its relationship with climate change. In this respect, the implementation of appropriate mitigation and adaptation strategies as well as the integration of these strategies inside urban planning tools is of outstanding importance. Mitigation strategies are related to the adoption of urban and land planning models that are able to counteract the development of UHI within urban environments, while adaptation strategies aim at reducing the impact of those phenomenon related to UHI, such as summer bioclimatic discomfort.

Pilot actions constitute the final phase of UHI project: they started as feasibility studies in order to evaluate how city space can be developed taking into account the mitigation and adaptation strategies developed in the course of UHI project. The development of pilot actions in the framework of mitigation and adaptation strategies represents another very important aspects of UHI project. The most relevant metropolitan areas in Central Europe are the pilot areas where pilot actions are developed (Budapest, Ljubljana, Modena, Padua, Prague, Stuttgart, Warsaw and Wien). In fact, UHI project aims at adopting urban and land planning models in order to prevent urban heat island effect and to reduce its impact. Pilot-areas have been identified by project partners inside each of the afore-mentioned metropolitan areas in Central Europe.

Trans-national Focus Groups (TFGs) are one of UHI project's operative tools to ensure maximum synergy between various partners and local stakeholders involved in the pilot actions. The rationale of TFGs is to encourage the exchange of ideas and best practices in a trans-national and multi-disciplinary context. Experts taking part to TFGs are non necessary limited to the partnership of UHI project,

rather it has been considered an enlargement of the expertise during the course of the UHI project.

Trans-national focus groups (TFGs) are trans-national thematic meetings where experts with a sound experience in UHI related topics, such as meteorological, climatic and biometeorological aspects, architectural techniques and urban planning debate on the issues related to UHI phenomenon. TFGs took place in conjunction with the formal project meetings established during the course of UHI project.

TFGs are conceived to manage the knowledge shared among partners and stakeholders, the debate developed in the TFG framework faced general and scientific issues that could support the activities carried out within the whole UHI project.

The items chosen as drivers of the debate are the following:

- Urban planning: urban sustainability, regeneration and sprawl limitation policies;
- Environmentally-driven consent: policy and communication (pro-active strategies aiming at an environmentally significant UHI accounting behaviour - attitude and context - addressing to citizens, planners, policy makers, researchers, etc.);
- Urban health: bioclimatic discomfort, human health;
- Urban meteorology: micro- and macro-scale analysis of the phenomenon.

TFGs can thus be considered as parallel insight that contribute to define the technical scenarios linked with UHI phenomenon. The methodological approach is based on the definition of general issue (for example, Urban planning) developed in different sub-topics acting as a pathway of the debate (for example, regeneration and sprawl limitation policies).

The discussion within TFGs dealt with generally developed problems and implemented scientific activities carried out in parallel in the context of the whole project: working groups may in fact be considered as a cross-cutting approach that helps to define technical scenarios associated with the phenomenon of urban heat islands.

A general objective of UHI project aimed at drawing a trans-national attention, as well as policies and practical actions, in order to prevent risks deriving from UHI, both from natural and anthropogenic origin. In particular, UHI project includes the review of a wide range of possible mitigation and adaptation actions for lowering the negative UHI effects within cities. Most of the actions that are commonly employed can be divided into three main types of intervention, namely buildings, pavements and vegetation.

As for buildings, the mitigation of their effects on urban heat islands are primarily related to the changes of material properties, as well as on the geometry of the urban settings created by buildings themselves (street sections and urban canyons). The first of the afore-mentioned strategies mainly deals with the thermal performance of buildings, while the other is mainly related with the way in which air currents can remove excess heat from areas between buildings (streets, passageways, etc.). Pavements in turn play a very important role in the formation of the UHI phenomenon, since conventional paving materials (concrete and asphalt among the others) tend to absorb large amounts of solar radiation during daytime and to release it to the cooler surrounding air at night. Another important property of paving materials is their limited permeability to water, which prevents water absorption in the ground, thus reducing the potential evaporation of the ground surface which may contribute to the reduction of air temperatures. Last but not least, trees and vegetation in general reduces ambient air temperature mainly by evapotranspiration and shading and is therefore expected to help in the mitigation process of UHI intensity. The common practices within this scope are the planting of trees and vegetation in an existing urban fabric (city streets and car-parkings) or the creation and the preservation of wider green areas (parks, groves, lawns, etc.) within the urban fabric.

UHI is obviously a common problem for Europe on a continental scale. Pilot actions brought together the most relevant metropolitan areas in Central Europe for a kind of shared study of the urban heat island phenomenon and for a joint experimentation of countermeasures.

UHI project structure deals also with the comparison of the impact of potential mitigation measures of the urban heat island through the use of different modelling tools in order to give a quantitative evaluation of the reduction of UHI intensity implementing the mitigation strategies. These estimate may also be an innovative strategy in order to support local stakeholders thus contributing to bridge the gap between two traditionally unrelated disciplines such as meteo-climatology and urban planning. The development of traditional meteorological models and the

analysis of relative outputs can in turn contribute to the definition of specific strategies to guide the choice of urban development and renewal.

The core of UHI project can be stated as an effort to create a positive relationship between knowledge and actions. Policy-making is a very complicated process partly due to the wide range of topics and uncertainty in the scientific results. Research in UHI project should aim at gaining a greater understanding of the complexities of meteorological issues with respect to mesoscale interactions, primarily at the urban boundary layer. One of the goal of this attention is certainly paid to put in place energy-efficiency and energy-saving approaches in urban and territorial planning.

In addition, systematic and interdisciplinary applied research can help policy makers to gather intelligence and to monitor and evaluate the efficacy of their approaches. On the other hand policy makers in urbanized and urbanizing regions can create opportunities to reduce the coupled impacts associated with rapid urbanization and changing urban climates as exemplified by the UHI effect.

That is policy makers at all levels should be able to craft policies, incentives and regulations matching economic, social and environmental imperatives. All of these issues are the directions toward which UHI project moved. Consistently, the partnership is a balanced (and quite strong) mix of policy makers on one side (namely “institutional partners”), and environmental monitoring agencies and university on the other side (namely “scientific partners”). All of them act within the orbit of the most relevant metropolitan areas in Central Europe.

PLANNING AND CLIMATE CHANGE: CONCEPTS, APPROACHES, DESIGN.

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Abstract. Reflect on the present, on the dynamics and the conditions that built it, and look forward at the same time, in search of a prospect to improve the future. Since Howard (1850-1928) and Geddes (1854-1932), this has been the dominant logic supporting the work of all those (architects, urban planners, planners, landscape architects, etc.) who grappled with city and territorial management and planning. However, from the 1970s territorial planning has been confronted with new concepts – such as sustainable development, environmental sustainability and social equity - and more recently, new challenges - such as the ones linked to climate change, which led to the need to redefine territorial planning in disciplinary and operational terms. For some years now, the planner's new role is under discussion, especially in relation to the challenges posed by climate change. Sustainability, mitigation, adaptation, renewable energy, low-carbon transition, ecosystem approach and post-disaster planning, are just some of the new keywords surrounding the discussion on territorial management and planning. This chapter aims to present rationally, what it means to re-organize and re-think the city, in a long-term perspective. It wants to show how it is possible, and above all is a duty to integrate the new concepts mentioned above in urban planning, to deal with the effects of climate change. The Urban Heat Islands contrast enters fully into the feasible experimentation with appropriate innovations in territorial planning. The paper draws attention to the Italian situation, in the light of the European reference framework.

Key words: Climate change, Adaptation, Policy, Urban Heat Islands, Urban Planning & Design

1. Introduction

Climate change has undoubtedly emerged as a crucial issue since the beginning of the twenty first century. According to IPCC predictions, the phenomena associated with climate variability will intensify in the coming decades (2007), and climate-related extreme events will constitute an increasing risk on a social and ecological level (2012). Over the past 20 years, the need to address the dynamics of climate change on an urban scale has been recognized at the institutional, academic and operational levels.

In this context, the challenges posed by the changing climate scenario require a redefinition of the urban and territorial planner's role, as well as revising the planner's skills and planning tools. In fact traditionally, planning has been based on the assumption that human activities are planned and implemented in an 'unchanging' context, characterized by stable regional and environmental conditions. The compressed environmental dynamics set in motion by environmental change and - more generally - the social, economic and environmental impacts related to climatic phenomena that occur in urban settings, even under emergency conditions, require the adoption of a new perspective and new tools, able to increase the adaptive capacity of cities compared to changes to the city, which are partially generated by the cities themselves.

The relationship between climate change and cities is rather complex and some of the challenges that planners will have to face, especially in terms of mitigation and adaptation can be identified with the effects of climate change. The contrast with the Urban Heat Islands (UHI) is one of the most obvious, intensified by global warming, which in the coming years will also have to be addressed structurally by urban and territorial planning.

2. Climate change and the city: a complex relationship

2.1 From sustainability to climate change: towards a new approach

With respect to when cities and territories were built, conditions are changing radically. Urban planning, as a discipline, was developed in the late nineteenth and early twentieth century, mainly as a response to the crisis of the times, related to hygienic needs, clean water, decent housing, open spaces, efficient transport systems and social welfare. During the twentieth century however, urban planning expanded to meet the emerging challenges of environmental protection, sustainable urban development and international cooperation (Wheeler, 2010).

To speak today of sustainability, in planning or in relation to territorial dynamics, is not easy, and requires attention. A first element to consider is the lack of consensus that exists with respect to the concept of "sustainable city". A second consideration is related to the perception of sustainabil-

ity, often viewed as an "abstract" goal, whose implementation is beset with difficulties. In addition, the perception of the city's decline has encouraged the integration of urban planning, economy and ecology, moving more and more towards an understanding of social, political and environmental sustainability disciplines (Musco, 2008).

If with the signing of the New Aalborg Charter in 2004, European local governments made specific commitments ranging from urban planning to new ways of life, from the economy to urban upgrading, it is with the Leipzig Charter on Sustainable Cities and the EU's Territorial Agenda (2007), that the strategies and principles for sustainable urban development policies in Europe were defined.

Nowadays, cities are facing a new crisis, which therefore requires a new perception of all the principles related to sustainability. Climate change goes beyond any previous human challenge, as it requires an integrated and dynamic approach.

Currently, the international scientific community recognizes climate change as a major challenge for the development and sustainability of the twenty first century (UNDP, 2005 and 2010, OECD, 2009; World Bank, 2012; UN-Habitat, 2011a and 2011b), for the revitalization of urban areas, and it recognizes two main aspects: (i) the difficulty of reaching a shared consensus for the reduction of greenhouse gas emissions (GHG) in international negotiations and (ii) the growing international consensus on the urgent need to build strategies to adapt to climate change on a national, regional and local level (Musco & Magni, 2014).

For this reason, during the last decade, urban areas have become central to the international debate on climate issues. The new geography of contemporary urbanization in fact identifies urban areas as a key element in the processes of globalization and transition to new land occupation models worldwide (Seto *et al.*, 2010). Therefore, today as in the past, if the task of planning is to reduce the risks and negative externalities and help provide answers to the concerns and aspirations that people express with respect to their living environment, it is necessary to step back and critically reflect on the concepts that underlie the planning and reformulate them in the light of new urban scenarios.

2.2 Mitigation and adaptation in the European agenda

The debate on climate change, supported by empirical evidence brought by the Stern Review (Cararo, 2009), followed by regular reports from the IPCC (2007, 2013), the EU report on temperature increases and the EEA's (2012) report on "Urban adaptation to climate change" in Europe, has become increasingly important within the urban issues. Climate protection can be generally defined as a set of indirect policies for adaptation and mitigation aimed at reducing the impact of climate change on natural and anthropized systems to the reduction of environmental externalities that may favour the climate changes in the medium and long term (Musco, 2009). This combined approach of policies to mitigate and adapt acquires a strategic value, since it allows different management

levels, multiple policy areas and a number of actors to be held together, both in terms of top-down and bottom-up.

State of the art "climate protection planning" in Europe is far from consistent. Each country is characterized by a national indication (national mitigation and / or adaptation plans and strategies), and the presence of local initiatives in terms of climate plans and local authority tools or networks. The latter's status varies widely from case to case and only a few local authorities have introduced adaptation, mitigation and energy efficiency strategies in the existing territorial planning systems.

Although a growing part of the scientific community (Betsill & Bulkeley, 2006; Biesbroek *et al.*, 2009; Musco, 2010), together with international institutions' research and policies (IPCC; EEA; EU White Paper, EC), recognize the role that territorial planning can play in addressing both the causes and consequences of climate change, the explicit translation of CC-problems into territorial policy measures and actual management is far from being reached.

In 2006 the publication of the Green Paper on Energy, "An European Strategy for Sustainable, Competitive and Secure Energy" raised the issue of energy efficiency and exploitation of renewable energy sources. This tool was followed in 2007 by the proposal of an action plan for energy efficiency (2007-2012) and a SET Plan (Strategic Energy Technology Plan). With the so-called "Climate and Energy" package, the EU has finally set a solid and binding goal for the member countries: 20% reduction in their greenhouse gas emissions (measured in CO₂ equivalent) by 2020 compared to 1990 levels, reduction in energy consumption by 20% compared to a "business as usual" scenario and production of energy from renewable sources accounting for 20% of final energy consumption. 2020 is not however a suitable timeframe for the resolution of problems related to the impacts of climate change. For this reason, the European Commission has already begun to explore the different scenarios ahead for post-2020. With the communication of 8th March 2011 ("A Roadmap for moving to a competitive low carbon economy in 2050), the Commission states that this transition goes through stages involving a reduction of greenhouse gas emissions by 25% by 2020, 40% by 2030, 60% by 2040, 80% by 2050 compared with 1990, thus surpassing the target set by the same package.

Although the implementation of policies and action plans is highly dependent on the national context and the various modes of urban governance, there are an increasing amount of experiences, programmes and projects that connect directly the local level, for the European Community, to the creation of new networks (Covenant of Mayors, GRaBS) or are based on already existing relations (Agenda 21, ICLEI, C40).

On this basis, local, regional and sometimes national authorities have begun to define, in many cases on an experimental basis, a series of plans aimed at protecting the areas from the effects of climate change.

3. Towards urban adaptation

Adapting to CC can be considered a "new" theme on the planning stage. The need to address the CC from a point of view of adaptation and not just of mitigation represents a substantial leap in scale, from a global logic for mitigation, to an urban and strongly localized one for adaptation. Adaptation is an urban and local issue, since it is very specifically the cities and the people that must find their "way" to adapt to the effects of CC that impact them and there are no appropriate policies and adaptive measures that are suitable to be applied anytime and in all contexts. Adaptation is a complex mechanism that is based primarily on the geomorphologic specificities of the place and the local community that lives in it with its customs and traditions, but the economy, infrastructure, and flows that characterize it must necessarily also be taken into account. Adaptation is therefore primarily a spatial, territorial concept, which cannot forcefully enter as a new standard in the elaboration of the theories and tools of the plan and the project of urban and territorial planning.

The need to face CC at an urban scale can be attributed to diverse considerations, that should be addressed in an integrative way. First, as partially highlighted in the previous section, CC became an issue in urban agendas in response to the necessity to face urban vulnerability, defined as "the degree to which people, places, institutions and sectors are susceptible to, and unable to cope with, climate change impacts and hazards" (UN-HABITAT, 2014). The higher vulnerability of urban contexts can be attributed to a series of factors, such as "their heavy reliance on interconnected networked infrastructure, high population density, large numbers of poor and elderly people and major concentration of material and cultural assets" (Carter *et al.* 2015: 4, see also EEA 2010). With this respect, a further consideration concerns climate change and risk perception: also due to the factors mentioned above, the impacts of Climate Change are mainly experienced at a urban and local scale. Secondly, the emergence of urban CC issues is related to the need to limit the urban drivers that cause pollution. Currently, cities are the main producers of greenhouse gases, and this incidence will steadily increase with the growing urbanization trend (UN 2008).

At the conceptual level, adaptation would adopt an integrated theoretical framework, capable of integrating Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) also considering their relevance for urban planning.

3.1 A new role for planning

The marginalization of territorial and urban planning in recent years has become an objective and consolidated fact. The reasons for this have been identified in the inability to understand how the city and the territory in general were changing (yesterday and today), in the progressive loss of a complex design idea in which space and society, physical and socio-economical dimensions, general concepts and specific action plans, interactions between scales and times interact constantly (Gasparrini, 2015; La Cecla, 2015; Benevolo, 2012). Considering the above, planning can and must (re-)play an important role by sharing the challenges established by CC, by ecological issues, the geo-strategic and environmental re-appropriation of our territories and our cities. The spread of environmental issues and CC can reshape planning discipline by focusing on water, soil, energy,

waste, accessibility/mobility, but also on concepts such as blue and green infrastructures, recovery and regeneration of marginal areas (*vague terrains*), the densely populated and widespread city. In addition, the issues of recovery and regeneration through environmental and ecological networks are closely linked to security (ANCE / CRESME, 2012), which opens a new and important line of research and design on "post-disaster planning." The many risks, as well as their dynamic and cumulative interaction, require planning strategies guided by adaptive logic in order to rethink the space we live in structurally and not limit ourselves to making buildings "safe".

What territorial and urban planning must do is be more attentive to the physical and social realities of the places, going further than just looking at the individual events and embracing the extreme complexity of each territory and city. Planning must be more attentive to the spatial project to recognize the peculiarities and opportunities and to ensure not only quality urban landscapes, but also externalities and interdependencies that only efficient and safe cities and territories can provide (Gasparini, 2015). The great environmental and spatial challenges posed by CC require visions and relations on a super-local and a place-specific scale at the same time: a continuous multi-scale attitude that links resilience and recovery tactics and strategies. It seems obvious that all these issues require a rethinking of the shape and use of the territory and the city through the integrated enhancement of environmental components, to counter the effects of the CC and at the same time to rethink the contemporary city by looking for a sustainable balance.

3.2 *New concepts*

Adaptation to climate change, broadly defined by the IPCC in 2007, and subsequently analysed in its various meanings in a lot of literature, can be divided into different types: (i) anticipatory, (ii) autonomous and (iii) planned. These three different aspects of the concept and adaptation strategies support a number of new slogans and tools that fill the discussion on territorial management and planning. If in recent decades, the concept of "sustainability" has become a key element of territorial urban development, and "adaptation" aims at laying the foundations for durability through specific strategies, measures and actions. Given the difficulty in predicting change of climatic parameters on different scales and different natural and anthropic components, adaptation strategies must be regulated by seeking not just to ensure the system's functionality, but also to take advantage of opportunities that may arise from the change. For this reason, in recent years, headway is being made in the idea of using an "ecosystem approach" (Grumbine, 1994; Christensen *et al.* 1996 Millennium Ecosystem Assessment, 2005) to mitigate and adapt to climate change and its effects (Doswald, N. & Osti, M. 2011; Naumann *et al.*, 2011).

The ecosystem approach concept is a way of thinking and acting in a science-based, ecological way, integrating the biological, social and economic conditions to achieve a socially and scientifically acceptable balance between the priorities of nature conservation, the use of resources and the division of benefits (sustainability). This approach attempts to remove the barriers between human economy, social aspirations and the natural environment, placing humans within the ecosystem models and aspiring to maintain the ecosystem's natural structures and functions, taking into con-

sideration emerging properties from the interaction of these systems. Given the holistic view, which sees man as an integral part of the natural system, and the aspiration to integrate policies and measures that affect the system, the use of this approach is proving to be a promising strategy to increase resilience of the cities and territories in response to growing pressures. In this perspective, the use of renewable energy sources and low-carbon transition does not just take on a role in mitigative strategies for reducing CO₂ emissions, but become key tools in adaptation strategies that follow an ecosystem approach. The measures and actions that are being taken at a territorial level from an adaptive viewpoint following an ecosystem approach are manifold. Examples of these are the planning and use of blue and green infrastructures, river corridors, overflow basins for storage of rain and river water, containment tanks for the management of river floods, becoming more frequent due to the change in extreme rainfall patterns, living roofs, reconstruction of ecological corridors.

In this perspective, a reflection should be done about the importance of defining adaptation plans totally integrated with mitigation strategies, as well as about the urgent need to provide cities with management and planning strategies to be adopted after extreme climate events (such as draughts, floods and urban heat waves).

In fact if mitigations reduces the causes affecting climate, adaptation plans are aimed at reducing the future vulnerability on cities and built environment, thus at anticipating the adverse effects of climate change and at reducing potential damages deriving from it. At the same, if potential impacts are not more avoidable, *post-disaster planning* and management seek to define long-term recovery strategies, and ultimately to transform cities in more sustainable and resilient places, also through the direct involvement of local communities.

Re-shaping cities in ways that enable to enhance their adaptive capacity does not mean to bring them back to the way in which they were before the change and/or the disaster, nor to modify their deepest nature and *raison d'être*. Redefining urban patterns in this contexts means to take the opportunities that are hidden behind the change and use them to rethink a more secure, sustainable and resilient future. For the development and implementation of adaptation and mitigation including post-disaster recovery strategies, cities must be considered in their complexity, and all their dimensions (spatial, geographical, environmental, social, economic and cultural) must be addressed.

The adoption of measures and adaptation actions should not, however, be a short and medium term response to the negative effects of climate change, but become part of a routine planning that recognizes in dynamic, changeable and resilient nature, a model to follow.

Controlling the effects of Urban Heat Islands is fully embedded in a new resilient planning aimed at reducing the impact of temperature change.

4. Conclusions: building urban adaptation – the main role of planners

The dynamics of climate change require a thorough review, not only of the approaches, but also, at the same time, of the Territorial Governance tools. Operating within a Climate Proof scenario, territorial planning will have to be able to identify territorial vulnerabilities and implement effective measures designed around the territorial characteristics of the vulnerable area. The local effectiveness of the adaptation action identified is not just attributable to its design, but also to the forms under which it is implemented.

Planning on all scales has so far only partially considered regulation of the relationship between climate, urban vulnerability and territorial planning, leaving room for activities and/or projects of a voluntary nature. The growing attention to these processes, however, has not yet led to suitable policy responses. It is more than ever evident that "climate protection" presents rather disjointed situations with cases in which adaptation plans and strategies have been introduced, and, on the other hand, realities where the risks and impacts are still undervalued despite the relevance of the phenomena in progress. In most Italian urban contexts, the impact of a changing climate is still just relegated to the civil protection. The main reasons can be traced to a shared lack of public awareness on climate variability and its territorial impact, to a slow response to extreme weather conditions due to lack of preparation and resources and a lack of public policies and regulations relating to urban and environmental planning designed to manage climate change.

It seems evident that adaptation, although by its nature being developed locally, needs to be supported by processes to integrate the different project and planning scales closely related to mitigation policies and efficiency of the urban scale.

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Part I
The Urban Heat Island – Evidence, measures
and tools

Chapter 1

Forecasting Models for urban warming in climate change

1.1 General Introduction

The working package WP 3 collects technical and scientific definitions and state of the art about the urban heat island phenomenon and further presents strategies to simulate future scenarios by using modelling systems. The knowledge review is a core output of action WP 3.1, giving a complete overview over the problem. It discusses methods to mitigate and adapt to the intensification of the UHI in Central Europe (CE) and beyond and further provides background information for local authorities related to urban planning, building and land use regulations in compliances with EU rules. The review is developed with the contribution of all PPs, scientific and institutional, in order to have main examples of excellences, best practices, innovative regulations and intervention put in act to face the UHI phenomenon.

Working Package WP 3.2 discusses regional climate model simulations and tries to give an estimation of future climate conditions (temperature, humidity, precipitation, wind speed, cloud cover, etc.) which may serve as outer conditions for the assessment of the UHI phenomenon in the cities of CE. The suitable simulations can be made e.g. with WRF or RegCM, especially when urban land use parameterizations involved, and statistical output on means and standard deviations of the meteorological variables can be supplied. The regional climate model uses available boundary conditions provided by existing global climate models. Statistical downscaling techniques can be used as well. Within the city structures, other microscale models are necessary to provide estimates of the local conditions, e.g. in street canyons.

The project partners being involved in this action try to show possibilities to simulate the effect of the Urban Heat Island and analyse its characteristic features for their city of interest. They try to set up models with different backgrounds also to account for simulation of mitigation scenarios counteracting this urban climate phenomenon, to work out plans about sustainable strategies for future urban planning together with the local stakeholders. The operators of these models contributing to this report are manifold. On the one hand side there are meteorological services like the HMS (Hungarian Meteorological Service) and research institutes like the KIT (Karlsruhe Institute of Technology). On the other side there are Universities like Prague and Freiburg or territorial alliances like ARPA Emilia Ro-

magna. In the following, the models used by the project partners trying to forecast the UHI are listed.

In the following, a broad range of different tools and studies are presented which have been carried out by the project partners in the course of the activities in working package WP3. The studies range from climate change projections for central European cities with the regional climate model (RCM) WRF, to regional climate modelling with RegCM and statistical downscaling approaches. Further, the microclimatic model RayMan is used to assess climate change on street scale and another study investigates urban effects by coupling a town energy model (TEB) to the surface modelling platform SURFEX.

All the information is collected by the working package leader PP5 – Karlsruhe Institute of Technology and presented according to the requirements introduced in the WP3 methodological document.

1.2 Overview of models and tools

Collection of models for investigating the extend of Urban Heat Islands and the impact of climate change for Central European urban regions in the course of WP 3 - activities

EnviMet(<http://www.envi-met.com/>)

- Commonly agreed to serve as primary model for simulating urban climatology and mitigation scenarios
- three-dimensional microclimate model designed to simulate the surface-plant-air interactions in urban environment
- typical resolution of 0.5 to 10 m in space and 10 sec in time.
- ENVI-met is a **Freeware program** based on different scientific research projects
- ENVI-met is a prognostic model based on the fundamental laws of fluid dynamics and thermo- dynamics. The model includes the simulation of:
 - Flow around and between buildings
 - Exchange processes of heat and vapour at the ground surface and at walls
 - Turbulence
 - Exchange at vegetation and vegetation parameters
 - Bioclimatology
 - Particle dispersion and pollutant chemistry
- Applied by TU Vienna, University of Friburg and others

WRF (Weather Research and Forecasting Model)

- Developed by the National Center of Atmospheric Research (NCAR)
- Mesoscale, numerical weather prediction model, which also can be used for climate modeling
- Nested to global circulation model ECHAM5/MPI-OM
<http://www.mpimet.mpg.de/en/science/models/echam.html>
- Open source, code downloadable from the web
- <http://www.mmm.ucar.edu/wrf/users/>
- <http://www.wrf-model.org/index.php>
- Applied by KIT, Germany

Statistical downscaling approach

- Using STREAM 1 simulations from ESEMBLES-Project (<http://www.ensembles-eu.org/>)
- Methodology and forcing that were defined by CMIP3 simulations contributing to IPCC AR4; CMIP3 (Coupled model Intercomparison Project)
http://www.pcmdi.llnl.gov/ipcc/about_ipcc.php
- Applied by ARPA-Emilia Romagna, Italy

Micro-Climatic Model RayMan to assess climate change on city scale

- Boundary conditions from ENSEMBLE model RT2B (<http://ensembles-eu.metoffice.com>) and REMO regional climate model (<http://www.remo-rcm.de>)
- Calculation of the Physiological Equivalent Temperature (PET)
- RayMan: calculation of short- and long-wave radiation fluxes affecting the human body and takes complex urban structures into account
- calculated mean radiant temperature, required for the human energy balance
- meteorological and thermo-physiological data as input
- open source: <http://www.mif.uni-freiburg.de/rayman/intro.htm>
- Applied by University of Freiburg

SURFEX combined with TEB (Town Energy Model)

- **SURFEX** (Surface Externalisée) is the surface modeling platform developed by Meteo-France
- computes averaged fluxes for momentum, sensible and latent heat for each surface grid box → boundary condition for meteorological model

- input land cover information from ECOCLIMAP database
- TEB: computes energy balance considering canyon concept
- ALADIN-Climate RCM as atmospheric forcing
- <http://www.cnrm-game.fr/spip.php?article145&lang=en>
- Applied by Hungarian Meteorological Service

Regional Climate Model RegCM (<http://users.ictp.it/RegCNET/regcm.pdf>)

- Boundary conditions from GCM CNRM-CM5 (<http://www.enes.org/models/earthsystem-models/cnrm-cerfacs/cnrm-cm5>)
- Community Land Surface Model v3.5 (CLM3.5) as an optional land surface parameterization
- Urban surface treated by coupling with Single Layer Urban Canopy Model linked to SUBBATS surface scheme
- Applied by Charles University, Prague

CLMM (Charles University Large Eddy Microscale Model)

- LES tool for simulation of the flow in microscales with complex terrain or structures solving CFD problems
- In addition to flow equations it includes transport equation for scalars like temperature, moisture and passive pollutants
- Applied by Charles University, Prague

1.3 Case studies

1.3.1 Projections of climate trends for urban areas in Central Europe using WRF

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A) Introduction

In 2050 the global fraction of urban population will rise to a level up to almost 70%, which means that around 6.3 billion people are expected to live in urban areas. Next to that development a rise of the global temperature of about 0.2 K per decade for the twenty-first century is projected within the range of the SRES scenarios of the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change - IPCC) for Europe (Wagner et al. 2013).

It's predicted, that extreme events are to increase in the future, which means more and heavier storms, precipitation events and thus increased danger of flooding, occurrence of heat waves or days with high air pollution, especially dangerous in combination with high temperature periods (Beniston et al. 2007).

This note describes how scenario simulations for Central Europe have been performed with a regional climate model based on global climate model scenario simulations.

B) Data and methods

Results from high resolution, multi-ensemble regional climate models are an essential input for many climate impact studies. In the course of the CEDIM (Center for Disaster Management and Risk reduction Technology) project 'Flood Hazards in a Changing Climate' (Wagner 2013) a multi model ensemble of high resolution 7km regional climate simulations for a present (1971-2000) and a near future (2021-2050) time period were conducted. To assess the climate change on regional scales, regional climate models (RCMs) were nested into coarser global circulation models (GCMs). For the bulk of the simulations the ECHAM5/MPI-

OM Model in T63 resolution (horizontal grid spacing of approximately 140x210 km at mid-latitudes) served as GCM. ECHAM5 is the fifth-generation atmospheric general circulation model developed at the Max Planck Institute for Meteorology, in that case it was coupled to the Max Planck Institute ocean model (MPI-OM). IPCC SRES (Special Report on Emissions Scenario) A1B forcing scenario served as boundary condition.

The spatial resolution of RCM simulations has steadily increased over the last decades. In the past, several larger ensembles were carried out to assess climate change, like for example in PRUDENCE (Christensen and Christensen 2007) with a resolution of 50 km or ENSEMBLES (Hewitt CD 2005) with a spatial resolution of 25 km. To get more information on this, please refer to the respective literature.

Using WRF (Weather Research and Forecasting Model) as regional climate model was one part of the contribution of the Institute of Meteorology and Climate Research (IMK-IFU) to CEDIM. To set up WRF, different steps had to be conducted to make reliable forecasts. Thus three different runs had to be carried out: one past climate run, one validating reanalysis run and the final future climate scenario run. Each of these runs had a calculation time of approximately 3 month (Wagner 2013). Covering Germany and the near surroundings it was possible to extract modeling results for urban areas (7x7km grid cells) contributing to the CENTRAL Europe Project. Thus, WRF is used in the following to illustrate the effect of climate change on urban regions within the area of central Europe

The regional climate model WRF followed a double nesting procedure, where the coarse nest covered an area of entire Europe with a resolution of about 50 km, whereas the fine nest consisted of Germany and the near surroundings (Fig. 1.3.1.1).

The fine model domain of 174 by 174 grid cells covers an area between 1.5 to 17.5° E and 44.5 to 54.5° N. The model resolution of 7 km implies that every urban area of interest is covered by at least one grid cell 40 vertical levels where used for both nests. For further specifications on model physics and modeling proceedings refer to Berg et al (2013) and Wagner et al (2013).

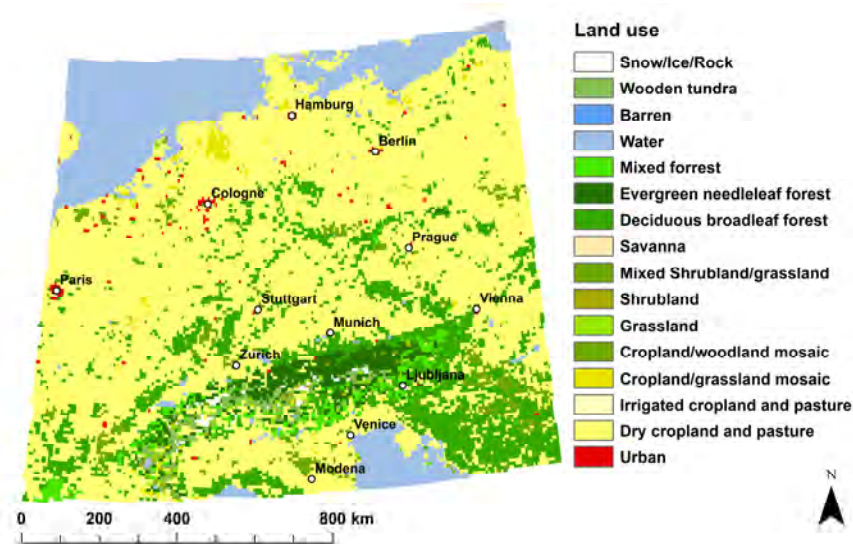


Fig. 1.3.1.1 WRF nested domain with 7 km horizontal resolution, showing USGS 2006 classified land use, projected on a LAT/LON grid with the coordinate system WGS 84 Zone 32N. The urban areas of interest are marked

C) Results

All simulation results project a significant warming throughout the model domain between 0.8 and 1.1 K. All ECHAM5 driven regional climate models predict an increase of annual precipitation in the range of 2 to 9% (average of 3% for Germany), with higher values in winter and autumn months. Using WRF as RCM reveals changes of temperature and precipitation (Wagner 2013). Differences in 2m temperature between future and past regional climate model run, extracted for certain urban areas located in the model domain and in the project region Central Europe reveal the following trends.

	DJF	MAM	JJA	SON	ANNUAL
Ljubljana	1.47	0.66	0.66	1.35	1.03
Modena	1.11	0.61	0.75	1.24	0.93
Padua	0.86	0.26	0.29	0.9	0.58
Vienna	1.92	1.04	1.13	1.91	1.5
Prague	1.43	0.05	0.07	1.13	0.67
Stuttgart	2.05	1.36	1.86	2.31	1.89

Tab. 1.3.1.1 Projected fine nest seasonal and annual temperature changes [°C] between 1971-2000 and 2021-2050 for the WRF simulation averaged for urban area

Monthly mean temperatures are extracted for one grid cell in the centre of a selected urban region to create probability density functions in order to statistically compare the modelling results. By calculating the values to fall below the 5 % confidence interval, the tendency towards extreme values is to be analysed on the basis of the comparison of the future (2021-2050) with the reference period (1971-2000). Probability density functions (PDF) for 4 selected cities are presented in Figure 2. Following the expectations given by the IPCC AR4, temperatures will develop in direction to the extremes (Beniston et al. 2007). The PDFs indicate a compression and widening of the future curve compared to that one of the past. The shift in the 95th percentile reflects the climate change signal.

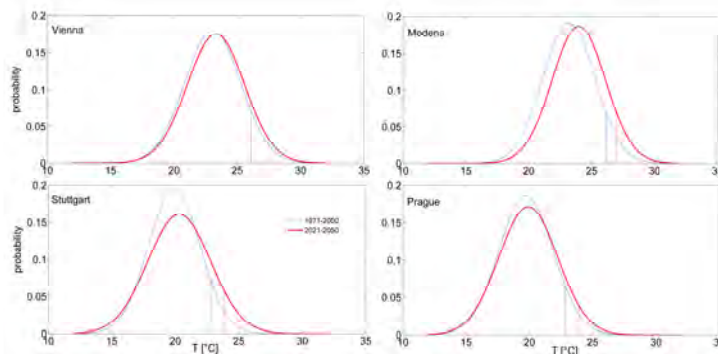


Fig. 1.3.1.2 Probability density functions (PDFs) extracted for the central 7x7 km pixel of a selected urban area. The blue line indicates the probability density curve for extracted monthly mean temperatures in the past (1971-2000), the red line shows the same for the future (2021-2050) period. The vertical lines illustrate the 95th percentile for each plot and time frame.

D) Conclusion

Delivering climate runs with higher resolution, which may fit better to the urban scale will be very cost intensive. Nevertheless, results from projects like the abovementioned one can be used as boundary conditions for high resolution city-scale models to conduct scenario runs (e.g. different urban planning strategies) for future climate conditions and region of interest. For further studies on impact of climate change on urban settlements please refer also to the project Ensembles-Based Predictions of Climate Changes and Their Impacts - ENSEMBLES (Hewitt CD 2005). This study can be used for other working packages dealing with mitigation and adaptation strategies, with the background that climate change will amplify Urban Heat Islands and future problems for urban inhabitants coming along with that phenomenon. Specific measures like urban greening, changing radiative properties of building materials or restructuring of city quarters, are not discussed in this report, rather should the results serve as basis for referring the problem of UHI's to a more global scale and thus to raise public awareness on a different level.

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1.3.2 Human-biometeorological assessment of changing conditions in the region of Stuttgart in the 21st century

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A) Data and Methods

Regional climate simulations of the ENSEMBLE RT2B model (for more information see <http://ensembles-eu.metoffice.com/>) with daily resolution are used as the data basis for the analysis of climate change in the greater region of Stuttgart for 1960-2100. The RT2B model focuses on the SRES A1B scenario. The regional climate model REMO (for more information see <http://www.remo-rcm.de/>) in hourly resolution and 10 km spatial resolution focusing on SRES A1B and B1 scenario is used to analyze the human thermal comfort conditions.

Therefore, the thermal index Physiologically Equivalent Temperature (PET; Höppe, 1993, Mayer and Höppe, 1987, Matzarakis et al. 1999) is calculated with the help of the micro-climate model RayMan (Matzarakis et al. 2007, Matzarakis et al. 2010). PET is used to quantify especially the frequency and intensity of heat stress. Thereby, PET between 18 °C and 23 °C was assessed to be comfortable, while PET above 35 °C (Nastos and Matzarakis 2012) stands for strong heat stress (Matzarakis and Mayer, 1996).

The dataset is used to calculate the number of climatologically event days and their change until the end of the 21st century.

Event		1961 - 1990	2021 - 2050	2071 - 2100
Extreme hot days	$T_{\max} \geq 39 \text{ °C}$	0 ± 1	1 ± 2	3 ± 5
Hot days	$T_{\max} \geq 30 \text{ °C}$	7 ± 9	12 ± 14	20 ± 24
Summer days	$T_{\max} \geq 25 \text{ °C}$	27 ± 19	37 ± 22	42 ± 38
Frost days	$T_{\min} \leq 0 \text{ °C}$	104 ± 29	79 ± 27	35 ± 30
Ice days	$T_{\max} \leq 0 \text{ °C}$	30 ± 13	18 ± 10	7 ± 8
Extreme cold days	$T_{\max} \leq -10 \text{ °C}$	1 ± 1	± 0	± 0

Table 1.3.2.1. Analysis of the number of climatological event days in the greater area of Stuttgart using the ENSEMBLE model RT2B for three different time periods 1961 - 1990, 2021 - 2050 and 2071 - 2100.

Results

Table 1.3.2.2 shows the frequency of climatological event days. The frequency of hot days ($T_{\max} \geq 30 \text{ }^{\circ}\text{C}$) and summer days ($T_{\max} \geq 25 \text{ }^{\circ}\text{C}$) will increase to 174 % and 140% in the period 2021-50 and 280 % and 157 % until end of the 21st century. On the other hand the number of frost ($T_{\max} \leq 0 \text{ }^{\circ}\text{C}$) and ice days ($T_{\max} \leq 0 \text{ }^{\circ}\text{C}$) per year will decrease to 33 % in the period 2071--2100.

The average annual air temperature might rise by $1.5 \text{ }^{\circ}\text{C}$ from 1961-1990 to 2021-2050 and $3.5 \text{ }^{\circ}\text{C}$ until the end of the 21st century (Table 2). Thereby, the increase in air temperature is strongest during summer and winter and weakest in spring.

Air temperature	1961 - 1990	2021 - 2050	2071 - 2100
Yearly	7.9 ± 1.7	9.4 ± 1.8	11.4 ± 2.1
Spring	6.7 ± 2.0	7.8 ± 2.3	9.6 ± 2.0
Summer	16.5 ± 2.5	18.0 ± 2.7	20.5 ± 3.4
Autumn	8.3 ± 1.8	9.7 ± 1.8	11.8 ± 2.4
Winter	0.1 ± 2.1	1.8 ± 2.1	3.8 ± 2.1

Table 1.3.2.2. The average annual air temperature simulated by the ENSEMBLE models RT2B and the standard deviation in the greater region of Stuttgart from 1961-1990 to 2021-2050 and 2071-2100.

The number of days per year with heat stress ($PET > 35 \text{ }^{\circ}\text{C}$) at 14:00 MEZ will increase by 6 days from 1961-1990 to 2021-2050 and by 28 days until the end of the 21st century according to the REMO data A1B scenario. The B1 data shows no increase until the mid of the 21st century, but an increase of 4 % (16 days) until 2071-2100 (Table 1).

In the early morning (6:00 MEZ), the number of days with (extreme) cold stress will significantly decrease by 15 (10) days according to the A1B (B1) scenario until 2021-2050 and by 48 (29) days until 2071-2100 (Figure 1). In contrast, the number of days with $PET > 29 \text{ }^{\circ}\text{C}$ will rise by 5 (15) days until the mid (end) of the 21st century according to the A1B scenario.

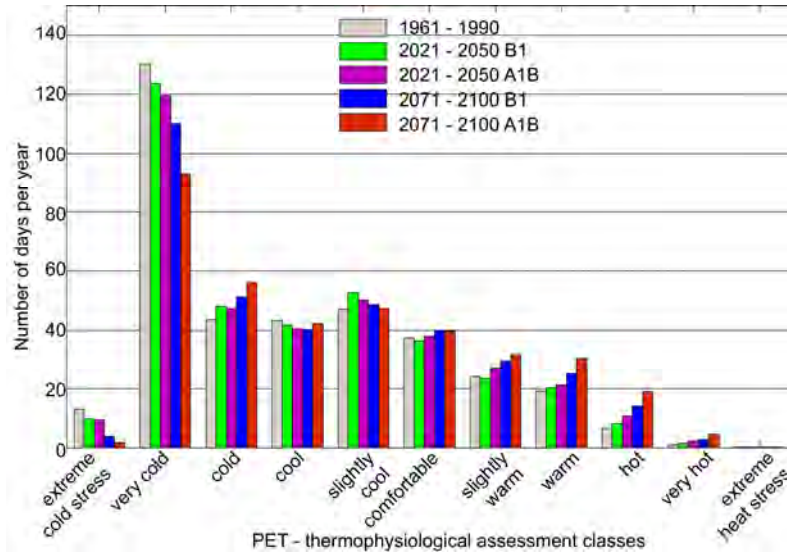


Figure 1.3.2.1. Number of days with PET assessment classes in the climate normal period 1961-1990 compared to the frequency in 2021-2050 and 2071-2100 at 6:00am. Data basis: REMO A1B and B1 scenario.

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1.3.3 Urban climate modelling with SURFEX/TEB at the Hungarian Meteorological Service

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A) Introduction

Half of the world's population lives in cities nowadays, which are continuously growing and have significant effects on local climate. Moreover, consequences of climate change in cities might be enhanced by the impact of urban surfaces. Thus, to make adaptation strategies to climate change, investigating these impacts is especially important. Therefore urban climate modelling activity started besides regional climate modelling at the Hungarian Meteorological Service (HMS) in 2010. To portray the interactions between the atmosphere and the urban areas, SURFEX surface model is applied. Main objective of using SURFEX is downscaling the regional projections for the future over Hungarian cities, and this paper is focusing on the first step of this, i.e. the validation of the surface model.

B) Methodology

The SURFEX (SURFace EXternalisée; Le Moigne 2009) surface model consists of four schemes for urban surface, sea, inland water and nature. Amongst these schemes the Town Energy Balance (TEB) model (Masson 2000) describes interactions between urban surface and atmosphere by simulating turbulent fluxes. It follows local canyon approach, where canyon represents the road with buildings on the sides. TEB considers three surfaces (roof, wall, road) with different energy budgets. It takes several processes into account which are important in urbanized areas, e.g., it treats water and snow interception by roofs and roads, fog, runoff, radiative trapping, momentum and heat fluxes. The anthropogenic heat and moisture fluxes derived from traffic, industry and domestic heating are also considered.

As input, SURFEX needs information about the atmospheric conditions, i.e. the atmospheric forcing, which can be supplied either by measurements or an atmos-

pheric model. The atmospheric model may be coupled with SURFEX and thus it can get feedback from the surface scheme, but SURFEX running in offline mode (i.e., without feedback) is feasible as well. It is noted that advection is not taken into account in SURFEX, thus there is no interaction between grid points in offline mode, which is only possible through the atmospheric model.

At HMS, the SURFEX studies started in 2010 (Vértesi 2011) for modelling urban heat island (UHI) effect in Budapest. Some 10-year long experiments were achieved over Budapest and Szeged. The atmospheric forcing was obtained from ERA-40 re-analysis (Uppala et al. 2005) produced by ECMWF (European Centre for Medium-range Weather Forecast). Re-analyses are three-dimensional climate databases, which are created with data assimilation technique using as many observations as possible plus short-range weather forecasts. ERA-40 is a global dataset at ca. 125-km horizontal resolution, which was downscaled by ALADIN-Climate regional climate model (Csimá and Horányi 2008) to a 10-km resolution domain covering the Carpathian Basin for 1961–2000. These results were interpolated by a special configuration of the model to two smaller areas around Budapest and Szeged at 1 km resolution (*Fig. 1.3.3.1*) for the investigated periods. These served as inputs for SURFEX, which was run in offline mode at also 1 km resolution. The information for the fine surface coverage and physiography was derived from the ECOCLIMAP database (Masson et al. 2003).

The first experiment was conducted over Budapest for 1961–1970. ECOCLIMAP was created in 2006, thus it might not describe the surface characteristics of the given period realistically, as several houses have been built since the 60s, especially in the outskirt. Therefore, the experiment was repeated for 1991–2000 to see whether these changes modify the results. For this latter period a simulation was achieved over Szeged as well to investigate the effect of urbanization in another location.

The results were validated against observations of HMS stations. In both cities two stations were selected: one in the centre and one in the outer part of the town. In case of Budapest the inner station is situated in Kitaibel Street, close to the Buda Hills, the other one operates in Pestszentlőrinc, in the outskirts (*Fig. 1.3.3.1*). However, ECOCLIMAP considers both points as temperate suburban (it is composed of 60% town and 40% nature). Szeged is located in the Southern Great Plain region, where higher elevated orographic objects (hills or mountains) cannot be found in the vicinity of the town. The surroundings of its inner observational site are also categorized as temperate suburban in ECOCLIMAP, while the outer point is actually a rural point without buildings. This paper summarizes the performance of the SURFEX model for these three experiments. Climate change assessment is not the aim of this study, since 10-year periods are insufficient for such investigations.

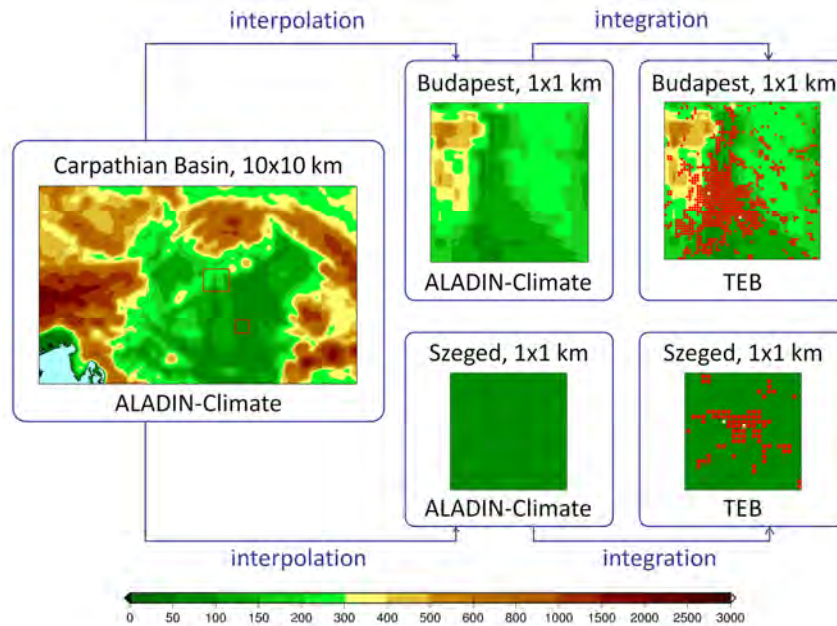


Fig. 1.3.3 Flow chart about the use of SURFEX with topography [m] and the gridpoints that include urban surface (right panels; red); white dots indicate the observational stations in the right panels

C) Results

Budapest

Figure 1.3.3.2 shows how the interpolation and SURFEX integration modify the original temperature field of ALADIN-Climate. The applied interpolation takes into account the 1-km resolution topography, therefore, some new orographic features appear in the middle panel, like the cooler Buda hills. As a result of the sophisticated surface schemes in SURFEX, its temperature field (right panel) shows much more detailed information, Danube becomes slightly visible and temperature excess appears over the heart of the city.

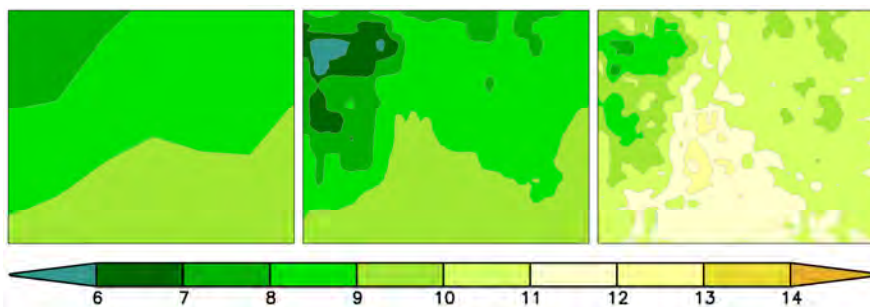


Fig. 1.3.3.2 Spring 2-m mean temperature ($^{\circ}\text{C}$) of ALADIN-Climate (at 10 and 1 km resolution – left and middle panel) and SURFEX (at 1 km resolution – right panel) over Budapest for 1961–1970 (Vértesi 2011)

In both reference points and periods mean intra-annual temperature differences between the SURFEX results and observations are very similar (*Fig. 1.3.33.*), and mainly reflect the behaviour of the bias of ALADIN-Climate (not shown). From May to September the model exaggerates the temperature, and in April very strong underestimation can be seen. In the concordantly overheated months, the results of Kitaibel Street are better, while in the rest of the year (except for April) this statement is valid only for the earlier period. Since ECOCLIMAP database provides information about recent surface characteristics, the reduced overestimation in Pestszentlőrinc in 1991–2000 compared to the results of 1961–1970 might be caused partly by the more realistic coverage description. (However, the fact that the improvements cannot be detected in every months indicates the key role of different atmospheric forcings in the two periods, especially in summer.)

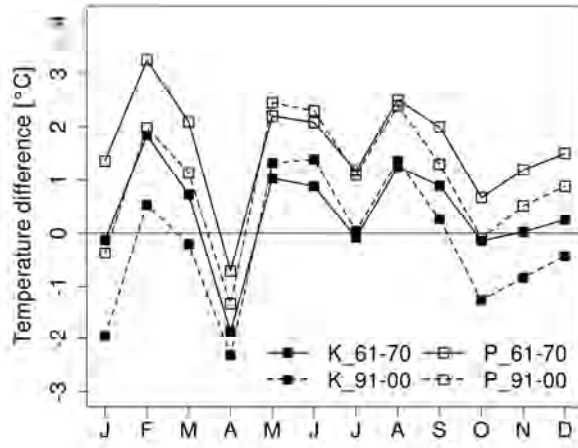


Fig. 1.3.3.3 Difference of monthly mean temperature (°C) between SURFEX and observation in Kitaibel street (filled squares) and Pestszentlőrinc (open squares) for 1961–1970 (solid lines) and 1991–2000 (dashed lines)

In contrast with the temperature measurements, urban heat island cannot be noticed in any periods of the year (*Fig. 1.3.3.4*), which means that the inner point is colder than the outer one in the model. This already appears in the ALADIN-Climate results, and SURFEX cannot improve this, especially because the two points are characterised with the same cover type in the ECOCLIMAP. Moreover, Kitaibel Street locates on higher elevation than Pestszentlőrinc, and the neighbouring of the Buda Hills to the inner site might cause too strong cooling in ALADIN-Climate compared to the observations (recall that SURFEX does not simulate interactions between the neighbouring grid cells).

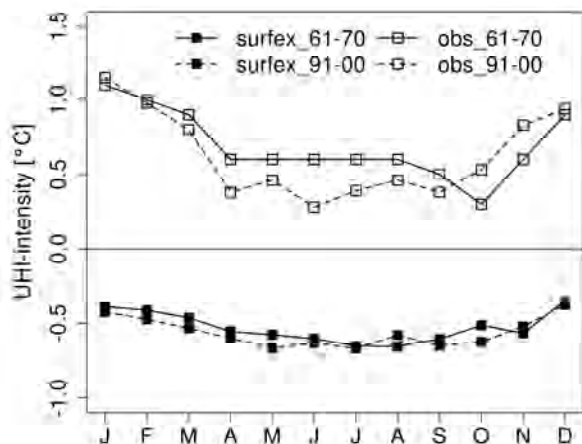


Fig. 1.3.3.4 Observed (open squares) and modelled (filled squares) urban heat island intensity (°C) in Budapest for 1961–1970 (solid lines) and 1991–2000 (dashed lines)

In the two reference points the results does not indicate good performance, but if a larger area is taken, SURFEX captures the daily cycle of UHI (*Fig. 1.3.3.5*). In daytime the air temperature of the city centre does not differ from the reference point in the suburban area; however after dusk (in winter already at 18:00, in summer at 21:00 UTC) UHI appears and its maximum intensity can be seen 5–6 hours after sunset. The physical reason is that energy supply by solar radiation ends after sunset and upward longwave radiation is much more effective over natural surfaces than in the densely built-in urban area due to the smaller heat capacity of soil and the trapping of radiation in urban canyons. (Basically the same conclusions were drawn for 1991–2000.)

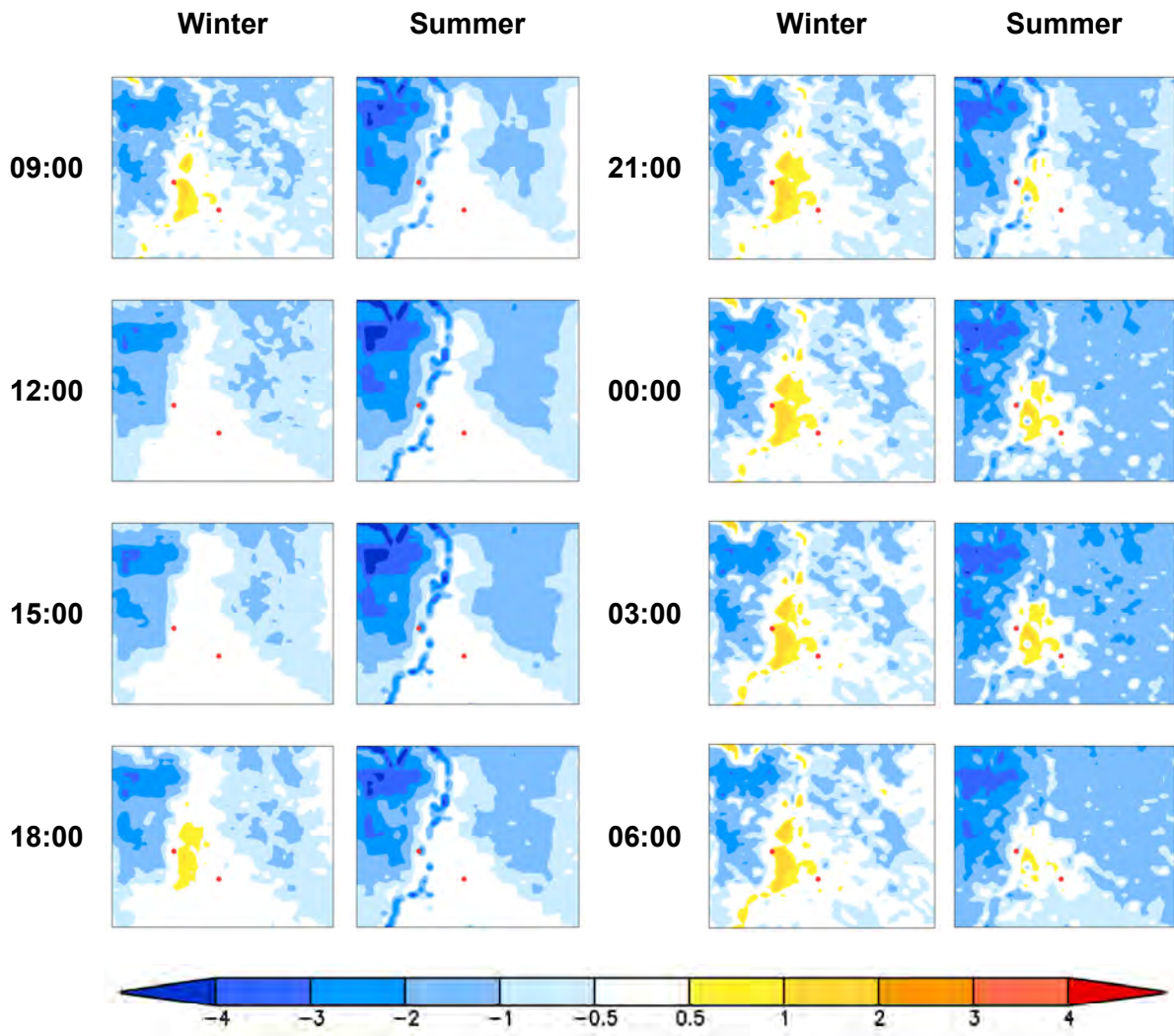


Fig. 1.3.3.5 Difference of simulated mean temperature (°C) from the value at Pestszentlőrinc (the outskirts point) in winter and summer for 1961–1970 (the two red points represent the selected stations in Kitaibel Street and Pestszentlőrinc)

Szeged

The meteorological measurements in the inner site of Szeged have started in May 1998, thus the validation was limited for 1999–2000. *Figure 1.3.3.6* presents the monthly average biases of ALADIN-Climate and SURFEX in the two reference points in this period. The annual cycles of the biases are similar to the result for Budapest. In general, SURFEX is giving more heat to the temperature fields of ALADIN-Climate, and due to the representative locations of the reference points (being in a flat area, and the outer point is situated in natural environment), the inner site gains larger warming to the extent that the difference between the bias of the two points almost diminishes. This implies that the monthly average UHI intensity is positive in all months (*Fig. 1.3.3.7*) and the magnitudes are represented adequately, as well.

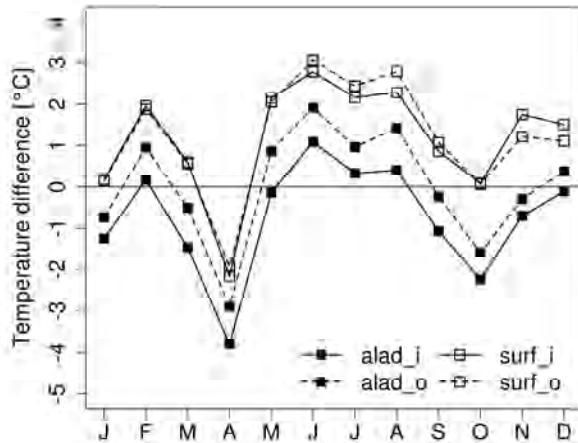


Fig. 1.3.3.6 Monthly mean temperature bias (°C) of ALADIN-Climate (filled squares) and SURFEX (open squares) compared to observations in the inner (solid lines) and outer site (dashed lines) of Szeged for 1999–2000

The average annual and daily cycle of UHI simulated by SURFEX in 1991–2000 (*Fig. 1.3.3.7*) follows the theoretical pattern, namely the largest intensity occurs in the nocturnal hours from May to September with a peak of 1.8–2.2 °C. In contrast, in the late mornings of summer and autumn the outer point can be warmer than the inner one, since they warm slowly due to the larger heat capacity of urban surfaces and the urban canyons form obstacles against low sun-rays. In December and January UHI feature can be seen all day, however the maximum intensities are lower than in summer.

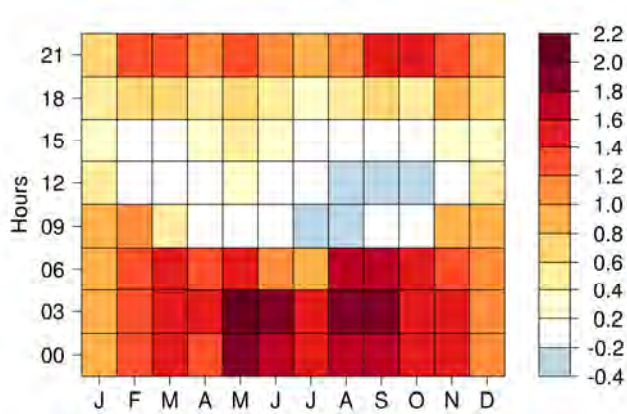


Fig. 1.3.3.7 Annual and daily cycle of UHI intensity (°C) in 1991-2000 between the two selected points in Szeged simulated by SURFEX

D) Summary

At HMS SURFEX dynamical scheme is applied to describe interactions between the atmosphere and the urban surfaces. Some 10-year long test simulations were accomplished with the model over Budapest and Szeged. In this paper preliminary results of these validation experiments are performed. Based on the results, SURFEX captures the main characteristics of the urban climatology: temperature excess in the heart of the city and daily cycle of the urban heat island. However, the evaluation indicated also some discrepancies: in the reference points SURFEX overestimates temperature in most months and in Budapest the central point is colder than the outer one, contrary to the observations. These errors derived partly from the atmospheric forcings and the inaccurate coverage description of ECOCLIMAP. Some additional investigations and test experiments are planned in order to examine the behaviour of the model in detail and develop its performance. Further goal with SURFEX is the dynamical downscaling of climate projections over towns, furthermore, supplying a reliable basis for impact studies in the cities for the future.

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1.3.4 Regional climate modelling considering the effect of urbanization on climate change in Central Europe

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A) Introduction

Big cities or urban agglomerations can significantly impact both climate and environment. The emissions of large amount of gaseous species and aerosols, which affect the composition and chemistry of the atmosphere (Timothy et al., 2009), can have adverse effect on the environment in the cities and their vicinity. Moreover, this can negatively impact the population (Gurjar et al., 2010). In addition, this pathway can result in indirect impact on the meteorology and climate as well, due to radiation impact of the atmospheric composition on the thermal balance and thus affect the temperature as well. Especially within the canopy layer in the cities, the changes can be quite significant.

However, the primary reason for temperature increase within the cities or urban agglomerations with respect to the rural vicinity, is the effect of so called urban heat island (UHI, Oke, 1973), which is mainly due to construction elements within the urban environment. This is extensively covered by artificial objects, buildings, using by large stone, bricks or concrete, and by quite large spaces often paved. This kind of surface clearly differs from natural surfaces (e. g. grassland, forest) by mechanical, radiative, thermal, and hydraulic properties, therefore, these surfaces represent additional sinks and sources of momentum and heat, affecting the mechanical, thermodynamical, and hydrological properties of the atmosphere (Lee et al., 2010). Nevertheless, the changes of meteorological conditions within the urban areas due to UHI can further affect the air-quality. This has been studied recently by e.g. Ryu et al. (2013), they found significant impact on the ozone day and night-time levels especially due to circulation pattern changes for the Seoul metropolitan area.

For WP3 we have focused on the aspects of climate conditions changes in urban environment, yet especially on those with strong potential to impact the air-quality, based on the experiment setup described below. For the region of Central Europe, we investigate the impact of the urban environment by means of its introducing into the regional climate model. As the spatial scale of the meteorological influence due to the cities is much smaller than the scale resolved by the mesoscale model, inclusion of urban land-surface requires additional parameterizations. The most common parameterizations considering the urban effects are the

slab models (bulk parameterization), where the urban surface constants (e.g., surface albedo, roughness length, and moisture availability) can vary to better describe those of the urban surfaces. This treatment however ignores the three-dimensional character of the urban meteorological phenomena, moreover, in feasible resolutions the urban environment cannot be well resolved. Therefore, a more accurate approach is provided using urban canopy models (single layered – SLUCM, or multi-layered MLUCM) coupled to the driving mesoscale model (Chen et al. 2011). Our study describes in more details the implementation of such a SLUCM into our regional climate chemistry modelling system.

B) BACKGROUND OF MODELLING FOR EUROPE

For the purpose of the climate simulations for UHI we follow two lines. First one aims to prepare up-to-date background information on the changing conditions in Europe using Euro-CORDEX rules. Euro-CORDEX is European part of the CORDEX initiative under WCRP which intend to provide downscaled information on climate change for individual continents around the world. It supposes to perform the coordinated simulations (i.e. for coordinated domains and periods), which results in creating large ensemble of model simulations, both for validation based on ERA-Interim reanalysis and/or historical runs with a GCM from CMIP5 driving an RCM. Especially for the historical runs, as well as the subsequent transient future runs, the matrix of GCMs and RCMs is expected to be quite large. While the resolution 0.44° (50km) has been selected as standard for the CORDEX, for Europe the resolution of 0.11° (12km) is emphasised as well. We participate in this activity with the model RegCM, both in evaluation experiment driven by ERA-Interim for 1989-2008 and transient historical and future run covering the period 1960-2100, at 50 km resolution, using scenario RCP4.5 for the future changes. As driving GCM, CNRM-CM5 is used. Figs. 1.3.4.1 and 1.3.4.2 show the validation of temperature for the simulations driven by ERA-Interim and CNRM model, respectively. Further, Figs. 3 and 4 present climate change temperature signal for near future (2021-50) and far future (2071-2100), respectively.

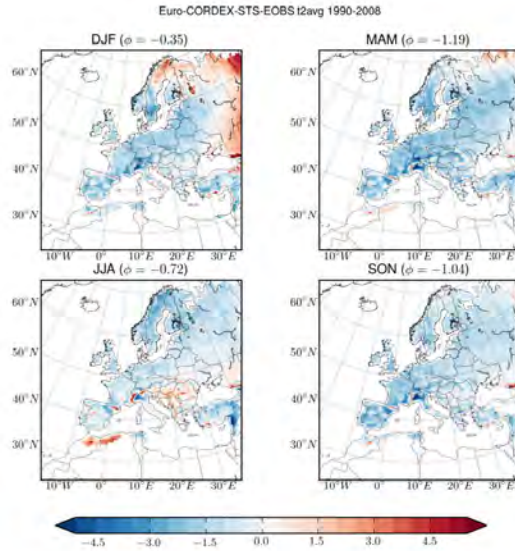


Fig. 1.3.4.1 The validation of model mean temperature in terms of the difference of the ERA-Interim driven simulation against E-OBS data, for temperature and individual seasons.

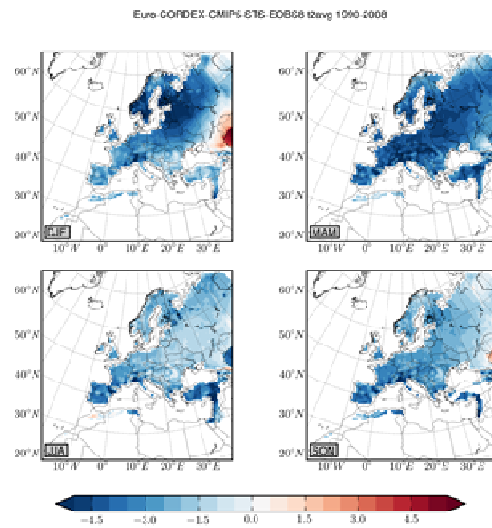


Fig. 1.3.4.2 The validation of model mean temperature in terms of the difference of the CNRM-CM5 driven simulation against E-OBS data, for temperature and individual seasons.

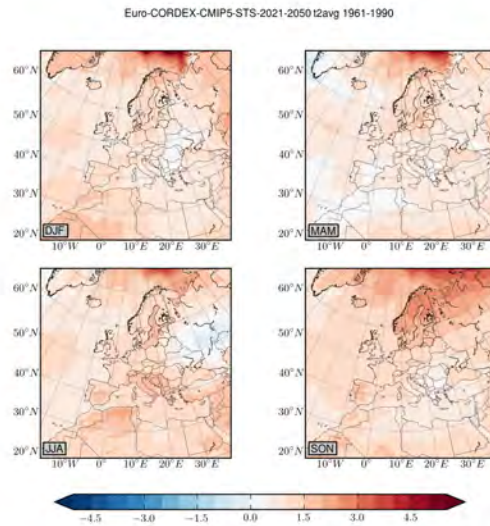


Fig. 1.3.4.3 The climate change signal for near future in terms of the difference of the CNRM-CM5 driven simulation 2021-2050 against 1961-1990, for temperature and individual seasons under RCP4.5.

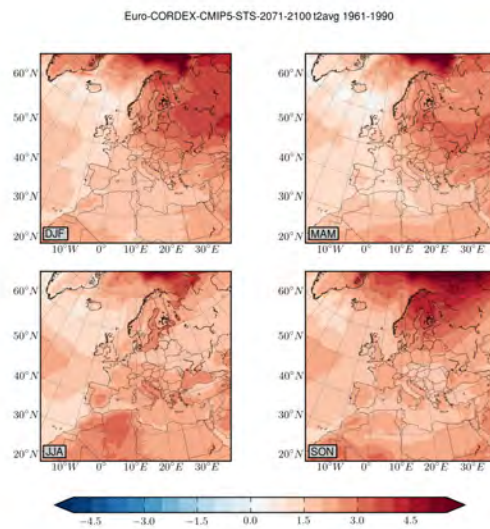


Fig. 1.3.4.4 The climate change signal for near future in terms of the difference of the CNRM-CM5 driven simulation 2071-2100 against 1961-1990, for temperature and individual seasons under RCP4.5.

The regional climate model we use is the model RegCM version 4.2 (hereafter referred to as RegCM4.2) from The International Centre for Theoretical Physics (ICTP), which is a three-dimensional mesoscale model. In terms of physical parameterizations it is based on RegCM3 (Pal et al., 2007) with many additional options. Major changes in the model from version 3 to version 4.2 include the following: the inclusion of the Community Land Surface Model v3.5 (CLM3.5) as an optional land surface parametrization, a new optional parametrization for diurnal SST variations, and a major restructuring (modularization) of the code base. RegCM4.2 and its evolution from RegCM3 is fully described by Giorgi et al. (2012).

RegCM4.2 includes a two land-surface models: BATS and the CLM model. Both land-surface models can work in mosaic-type mode where the model grid is divided into sub-grid boxes for which the calculation of fluxes is carried out separately and the fluxes are then aggregated back to the large scale model gridbox (for BATS scheme referred as SUBBATS, see Pal et al., 2007). While in Europe scale we used standard BATS scheme, for the second line aiming to get high resolution downscaling with effect of urban parameterization included we have selected the SUBBATS on 1 km grid, which enable to identify clearly urban and suburban types of the land-use.

C) URBAN PARAMETERIZATION AND EXPERIMENTAL SETUP

Cities affect the boundary layer properties thus having direct influence on the meteorological conditions and therefore on the climate. The urban surface is covered by large number of artificial object with complex 3 dimensional structure and considerable vertical size. Specific characteristics in urban morphology can be involved in complicated physical processes such as increased momentum drag, radiation trapping between buildings (effect of vertical surfaces), and heat conduction by the artificial surfaces. There had been many field measurements in cities that found characteristic features of mean flow, turbulence and thermal structures in the urban boundary layer (e.g. Allwine et al., 2002; Rotach et al., 2005).

Although there is a trend (enabled by the faster computational resources) to increase the spatial resolution of the mesoscale models, regional weather prediction and climate models still fail to capture appropriately the impact of local urban features on the mesoscale meteorology and climate without special sub-grid scale treatment. This accelerated the implementation and application of urban canopy sub-models (Chen et al., 2010 or Lee et al., 2010). For the regional climate model RegCM4 we have chosen the Single Layer Urban Canopy Model (SLUCM) developed by Kusaka et al. (2001) and Kusaka and Kimura (2004); this scheme is proven to perform well in simulating the urban environment and it is less demand-

ing in computational resources unlike its multi-layer counterparts (Lee et al., 2010).

SLUCM considers the urban surface in a realistic way: it assumes street canyons with a certain width; in the street canyon, shadowing, reflection and trapping of radiation are considered. An exponential wind profile is prescribed. SLUCM treats surface skin temperatures at the roof, wall, and road and temperature profiles within roof, wall and road layers as prognostic variables. The heat fluxes from each surfaces are calculated using the Monin-Obuchov similarity theory and finally the canyon drag coefficient and friction velocity is computed using a similarity stability function for momentum. Fig. 1.3.4.5 presents the conceptual design of SLUCM with the fluxes between street canyon air and the surrounding surfaces (road and walls) and the fluxes from/to the building roofs.

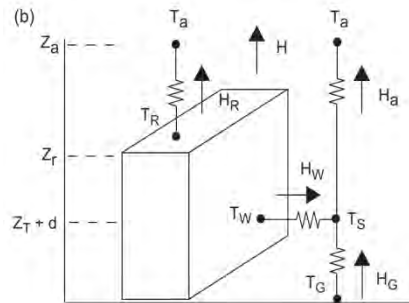


Figure 1.3.4.5 Energy fluxes in the SLUCM between the street canyon and the road and walls and from the buildings roof (T_a - air temperature at reference height z_a , T_R - building roof temperature, T_W - building wall temperature, T_G - the road temperature, T_S - temperature defined at $z_T + d$, H - the sensible heat exchange at the reference height, H_a is the sensible heat flux from the canyon space to the atmosphere, H_W - from wall to the canyon space, H_G - from road to the canyon space, H_R - from roof to the atmosphere) (following Kusaka et al., 2001)

For high resolution downscaling with dynamic resolution of 10 km for the Central Europe we use SUBBATS scheme at 1 km resolution as already mentioned above. However, as the parameterization used till now in RegCM4 did not recognised the urban effects, an improvement can be achieved by implementing more sophisticated urban parameterizations lying under these land-surface models that better represent for the urban land-use type most urban features like building morphology, street geometry, variability of the properties of artificial surfaces, as well as the description of radiation trapping in the street canyon. For this purpose, Chen et al. (2010) provide a Single Layer Urban Canopy Model (SLUCM), originally developed by Kusaka et al. (2001) and applied in Kusaka and Kimura (2004).

This SLUCM model has been implemented into RegCM4.2 by linking it to the BATS surface scheme, applying SUBBATS with 1 km x 1 km sub-grid resolution. SLUCM is called within SUBBATS wherever urban land-use categories are recognized in the land-use data supplied. The scheme returns the total sensible heat

flux from the roof/wall/road to BATS, as well as the total momentum flux. The total friction velocity is aggregated from urban and non-urban surfaces and passed to RegCM's boundary layer scheme. However, as RegCM4.2 by default does not consider urban type land-use categories, we extracted the urban land-use information from the Corine 2006 (EEA, 2006) database and we have added this information to the RegCM4.2 land-use database. In those parts of the domain where this was not available in Corine data, the GLC2000 (GLC, 2000) database was used. We considered two categories, urban and suburban. See Fig. 6 for the urban land-use coverage for the SUBBATS 1 km x 1 km subgrid module.

The domain for the present study has been selected to cover most of Central Europe with a spatial resolution of $10 \text{ km} \times 10 \text{ km}$. It is divided into 23 vertical levels reaching up to 5 hPa. For convection, we have used the Grell scheme (Grell, 1993). RegCM4.2 is initialized and driven by the ERA-Interim reanalysis (Simmons et al. 2007). The time step for the integration is 30 s.

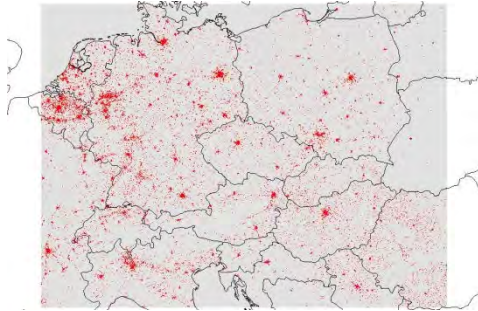


Fig. 1.3.4.6 Urban and suburban land-surface categories at 2 km x 2 km resolution.

D) RESULTS

Fig. 1.3.4.7 presents the change of selected meteorological parameters between experiments SLUCM (the urban canopy model turned on) and NOURBAN (urban canopy not considered) averaged over years 2005-2009. Shaded areas represent significant changes on the 95% confidence level. We show only winter (left panels) and summer (right panels) seasons, actually, the effect is well expressed in spring and autumn as well, but summer signal is stronger.

For temperature, there is an evident increase with urban canopy introduced in summer, for winter only slight signal can be seen for big cities like Berlin and Vienna, similarly for urban and industrial areas like Rhine-Ruhr region and Po-valley. In summer, this temperature increase can be of 1K over urbanized areas (effect of cities like Budapest, Vienna, Prague, Berlin are well seen), but it is statistically significant elsewhere with up to 0.4K increase even over non-urban areas. Opposite effect can be seen for specific humidity. Urban surfaces can absorb less water vapor than other surfaces and they represent a sink for the precipitated water as well. Therefore the evaporation from the urban surfaces is reduced as well which leads to the lower humidity over urban areas as seen in Fig. 1.3.4.7. Again, this decrease is highest above cities (up to -0.8 g/kg), but significant decrease is simulated over non-urbanized areas as well, up to -0.3 – -0.4 g/kg. Signal is quite strong in summer, but similar patterns, although much slighter, can be seen in winter. For wind speed, introducing the urban canopy parameterization leads to stronger wind over the surface (Fig. 3). This increase is limited mainly over urban areas where it can reach 0.4 – 0.6 m.s-1 in summer, much less it is expressed in winter, when for Po-valley there is even decrease. However, the signal is rather small in winter and not so much significant in all the domain. The increase above the cities in summer has to be further studied, one possible reason might be support of convection above the city with stronger winds in the bottom. Finally, we assess the effect of urban canopy parameterization on the height of planetary boundary layer from the model, which leads to statistically significant increase in summer above most of the domain, with quite strong signal above the cities and industrial regions (Fig. 7) of about 100-150 m, mostly negligible and not significant in winter.

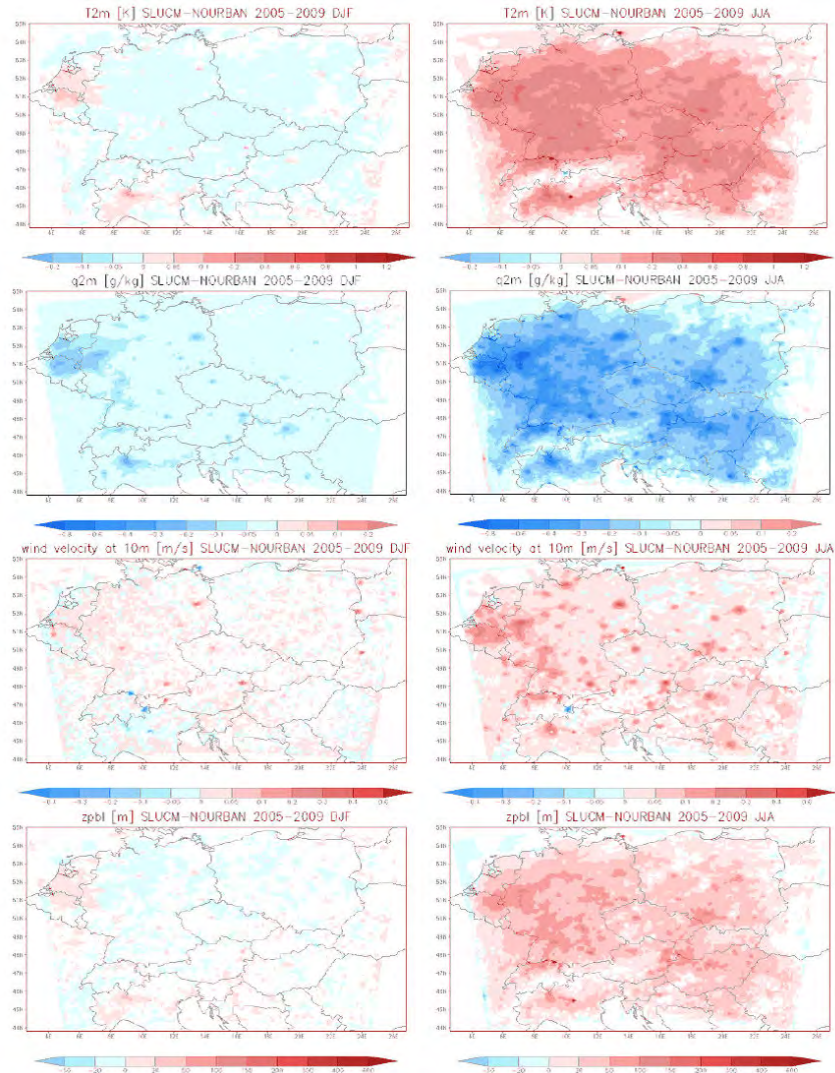


Fig. 1.3.4.7 The mean differences of meteorological parameters between experiments with SLUCM against NOURBAN averaged over 2005-2009 for winter (left panels) and summer (right panels): from the top - temperature at 2 m (K), specific humidity at 2 m ($\text{g}\cdot\text{kg}^{-1}$), wind speed at 10 m ($\text{m}\cdot\text{s}^{-1}$), and planetary boundary height (m). Shaded areas represent significant changes on the 95% level of confidence.

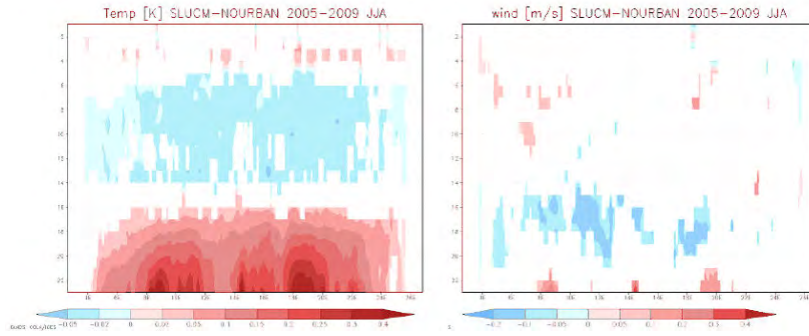


Fig. 1.3.4.8 The mean differences in summer between experiments with SLUCM against NOURBAN averaged over 2005-2009 for vertical cross-section on 50N of temperature (K, left panel) and wind speed ($\text{m}\cdot\text{s}^{-1}$, right panel). Shaded areas represent significant changes on the 95% level of confidence.

Fig. 1.3.4.8 presents the more detailed analysis of significant patterns of vertical structure of the urban parameterization effects in summer. The increase of temperature in the boundary layer is accompanied with temperature decrease above, concerning the humidity there is no effect in the free atmosphere (not shown). Stronger wind can be seen only at surface level, the effect throughout the boundary layer is rather negative.

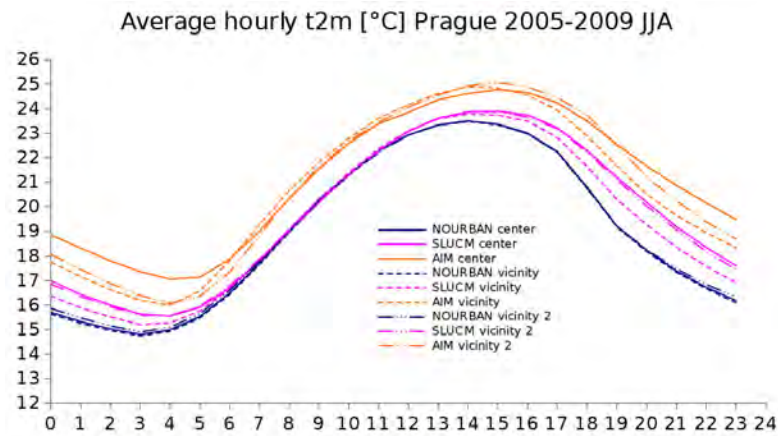


Fig. 1.3.4.9 Daily course of 2m temperature for Prague city center and two points in vicinity, where number 2 is rather suburban. The simulation without urban effect included is shown in blue, with the effect included in violet and observations are in orange. Summer season is shown.

In Fig. 1.3.4.9, the daily courses of surface temperature (2 m) are shown for Prague, with more detailed analysis of the simulations with respect to the observation data. In summer the strongest effect is shown, with clear extension of high temperature in evening hours both in city center data and in the simulation with urban effect included, to some extent as well in case of the second vicinity point, which has rather suburban character and it seems to be interpreted by the model with similar patterns as urban. Underestimation of the temperature in both simulations is evident, but especially during afternoon and night hours the urban effect contribute toward the bias reduction. Similar effect is clearly seen in comparison of simulations for other selected cities of the Central Europe in Fig. 10 in annual course, with E-OBS data shown as well. Again, introduction of the urban effect results in bias reduction in warm part of a year.

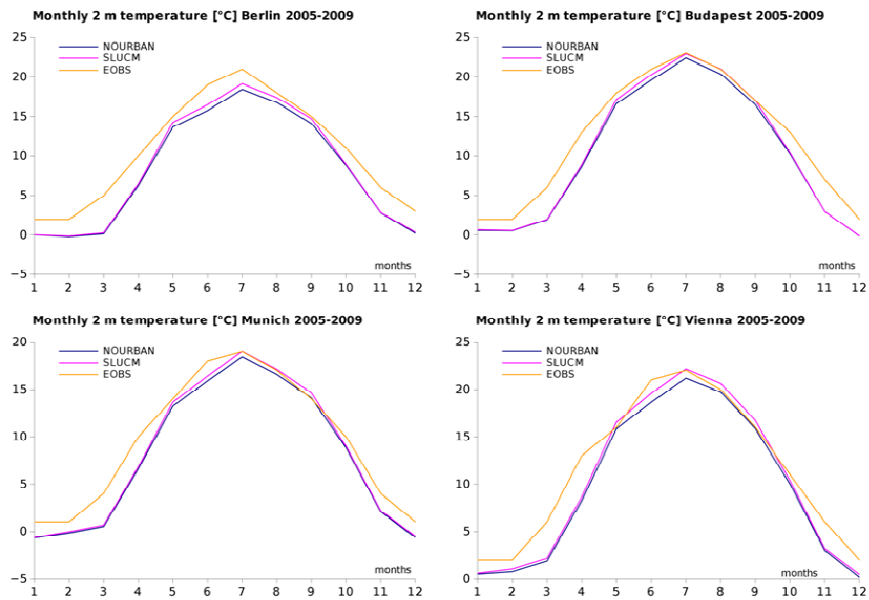


Fig. 1.3.4.10 Annual course of 2m temperature for selected cities based on the simulation without urban effect included (blue curve) and with the effect included (violet), compared to observations (orange).

E) SUMMARY

We have prepared the modelling stream for the assessment of the urban environment patterns and their changes due to both climate and other land-use or city structure changes. We have completed the decade 2021-2030 high resolution downscaling with respect to the pilot action in Prague, where city authorities are interested rather in closer future. Having both only BATS and SUBBATS results we can assess the effect of the urban environment. The analysis of other EuroCORDEX results can provide the information on the uncertainty or the spread of the local changes. Finally, we are running the CTM CAMx coupled with the RegCM4 to assess the impact of the changes on air-quality. The changes of emissions will be taken into account as well. Moreover, CLMM model is used to get effects in street canyons.

We successfully implemented a single layer urban canopy parametrization into the regional climate model RegCM4.2. Preliminary assessment is based on present day conditions simulation for 5 year long period with and without urban canopy parameterization included. Our simulations have shown that the impact on meteorological parameters is significant not only over urbanized areas but also over rural ones far from cities. The most important impact is the increase of surface temperature (up to 1 K), decrease of humidity, increase of surface wind speed, decrease of precipitation (not shown here) and increase of boundary layer height.

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1.3.5 Statistical downscaling techniques applied to ENSEMBLES GCMs: Bologna-Modena case study

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A) Introduction

Another tool used by the scientific community in order to construct future climate projections is the statistical downscaling techniques (SDs). One of the main advantages of this technique is that it produces information at local scale, station or grid points and it is not expensive in terms of computational time. One major problem for all tools that produce climate change scenario is to quantify and reduce the uncertainties that appear in modelling processes. Particular attention has been paid on this problem and many projects have been focused on this issue. One of this is Ensembles project (<http://www.ensembles-eu.org/>), where it was recommended use of a range of models over the same area and construction of an ensemble mean (EM). This technique has been applied in the present work, in order to produce climate change scenario over Bologna-Modena case study selected in the project.

B) Data and Methods

The SDs model developed by ARPA-SIMC, is a multivariate regression based on Perfect-Prog approach, built using observed local fields at station level, and large scale fields derived from re-analysis data set. A set of 75 stations distributed over N-Italy, including Bologna station, that measure minimum and maximum temperature and the large scale fields from ERA-40 reanalysis, over the period 1960-2002 has been used in order to set-up SDs model. Once the most skilful model is selected for each season and predictand, this is then applied to the predictors simulated by AOGCMs experiments in the framework of A1B emission scenario, such as to evaluate the local future scenarios of seasonal temperature. The SDs scheme here proposed use as predictors a selection of fields between mean sea level pressure (MSLP), 500hPa geopotential height (Z500), and temperature at 850 hPa (T850), already tested over Emilia-Romagna and N-Italy region (Tomozeiu et al.,2013). These fields (predictors) derived from ERA40 re-analysis

(<http://www.ecmwf.int/products/>) have a spatial resolution of $1.125^{\circ} \times 1.125^{\circ}$, cover the window 90°W - 90°E and 0° - 90°N and are referred to the period mid-1957 (September) to mid-2002 (August). As regards the AOGCMs predictors from the ENSEMBLES –STRAEM1 (Van der Linden, P., Mitchell, J B., 2009) runs had been used, over the period 1961-1990 (control-run) and 2021-2050 (A1B scenario). These fields are archived in the Climate and Environmental Retrieval and Archive (CERA data base) of the World Data Center System for Climate (WDC) and the access at the data is given by <http://ensembles.wdc-climate.de>. The STREAM1 simulations (<http://www.ensembles-eu.org/>), used in the present work have been performed with the methodology and the forcing that were defined for the CMIP3 simulations contributing to the IPCC AR4 assessment. Thus, the experiments were done using a common set of agreed forcing for historical simulations over the period 1860-2000, and for the three IPCC scenario A1B, A2, B2, over the 21st century. The scenarios were started from an initial condition obtained for year 2000 in the historical simulation. Several runs, produced by the following modelling groups have been take into account in the present work: INGV, NERSC, FUB, IPSL, METOHC (2 runs), MPIMET+DMI. The statistical downscaling scheme (CCAReg scheme) was applied to each seasons and each predicands (seasonal minimum and maximum temperature). The presence of different AOGCMs gives the opportunity to construct an Ensemble Mean (EM) of climate projections. The results obtained by applying the outputs of the AOGCMs to the CCAReg scheme at Bologna station are presented bellow.

C) Results

The future changes are presented in terms of probability density functions (PDFs) of seasonal minimum and maximum temperature, which provide a good estimation of changes not only in the mean but also in the extreme values. As could be noted from Figure 1, that presents the PDFs of changes in winter minimum temperature as projected by the CCAReg scheme applied to each AOGCM, all the outputs emphasizes an increase in the winter Tmin between 0.7 (BCCR and ECHAM5 models) up to 1.8°C (IPSL and EGMAM run2), over the period 2021-2050 with respect to 1961-1990.

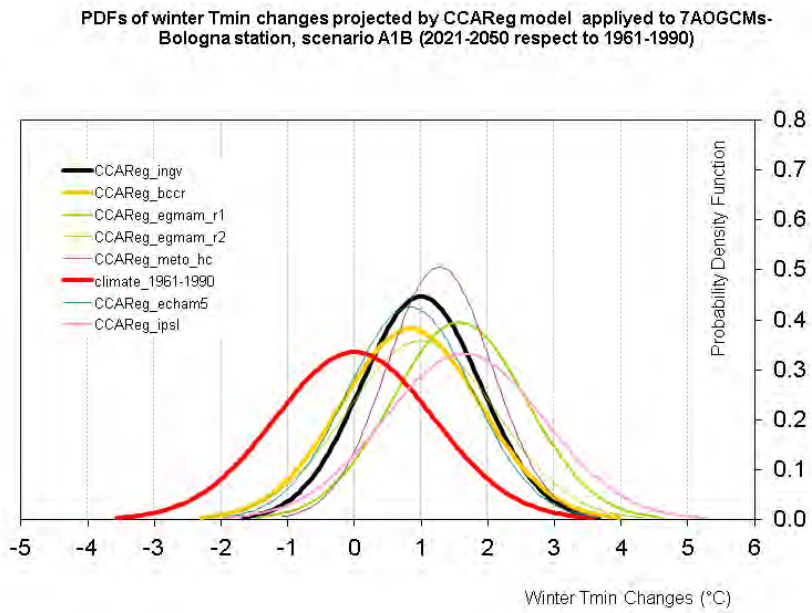


Fig. 1.3.5.1 Climate change projections of winter minimum temperature-Bologna station, scenario A1B, 2021-2050

As concerns the other seasons, the Ensemble Mean of changes in minimum temperature computed taking into account all runs, reveals an increase of temperature in all seasons (see Figure 1.3.5.2), around 1.5°C during spring and autumn and 2.5° C during summer.

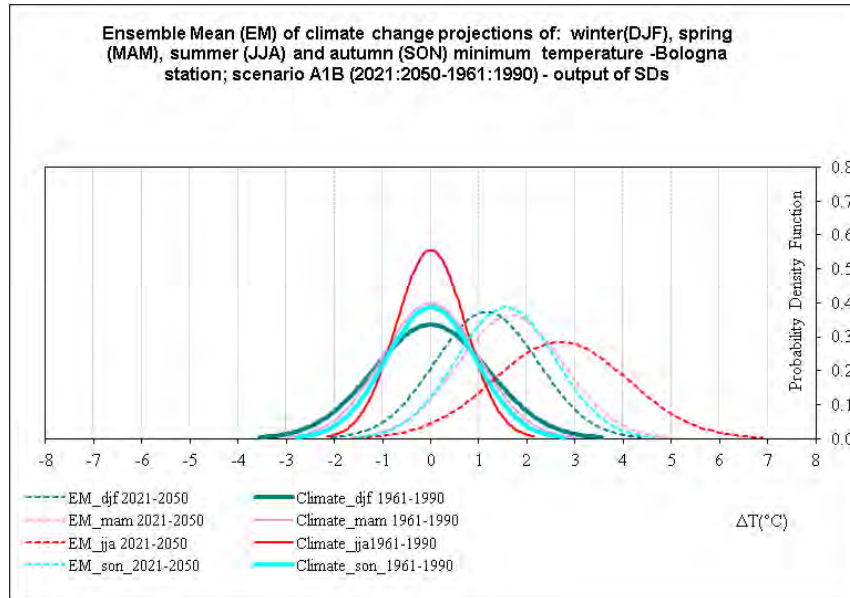


Fig. 1.3.5.2 Ensemble Mean (EM) of seasonal changes of minimum temperature projected at Bologna station (CCAReg model), scenario A1B, 2021-2050 with respect to 1961-1990

A similar signal of warming has been projected in seasonal maximum temperature. As it could be noted from Figure 1.3.5.3, that presents the Ensemble Mean of changes in seasonal maximum temperature, the projected warming is around 1°C during winter, similar with those projected in minimum temperature. During spring and autumn the maximum temperature is projected to increase with 2°C (central moment of the distribution) with respect to 1961-1990. The peak of warming is projected to appear during summer season when the changes will be around 2.5°C (central moment of the distribution).

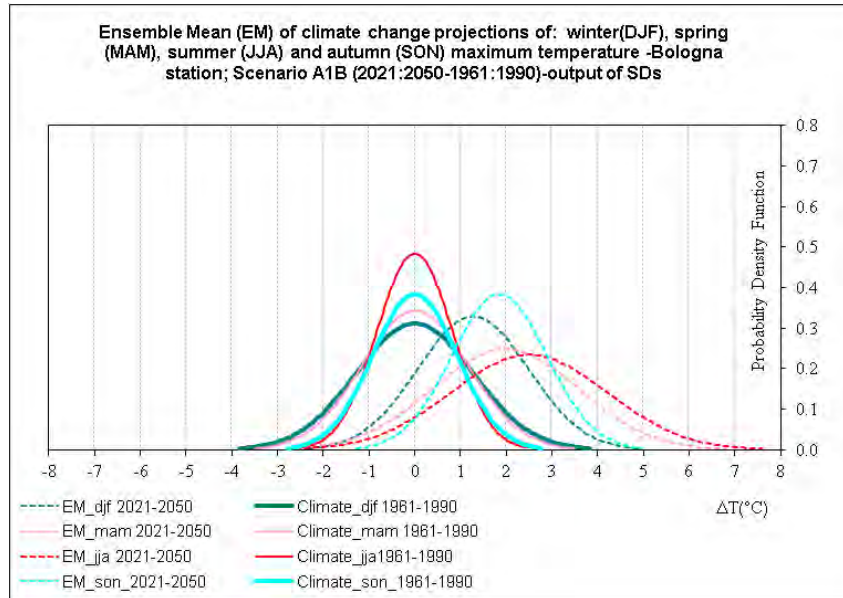


Fig. 1.3.5.3 Ensemble Mean (EM) of seasonal changes of maximum temperature projected at Bologna station (CCAReg model), scenario A1B, 2021-2050 with respect to 1961-1990

Analyzing the PDFs of changes in seasonal minimum and maximum temperature (Fig 1.3.5.2 and 1.3.5.3) it could be noted that all projected distributions (dashed curves) tend to shift to warm values with respect to present distributions (continuous curves). In addition significant changes could be noted not only in the central moment of the distribution but also in the tails, more significant in the upper tails of summer minimum and maximum temperatures when the 90th percentile could reach changes of 5°C. A signal of increasing could be noted also in 10th percentile of minimum temperature, especially during summer. This could connect to an increase in the heat waves (days with $T_{max} > 90$ th percentile of T_{max}) and number of tropical nights ($T_{min} > 20^{\circ}\text{C}$) over Bologna during the period 2021-2050 with respect to 1961-1990. In fact, the downscaling of the heat wave index for each season emphasizes a possible increase in the future 2021-2050 with respect to 1961-1990. Fig 1.3.5.4 presents the climate scenarios of seasonal heat wave at Bologna, present and future climate. As could be noted significant increase is projected during summer season, followed by spring and autumn.

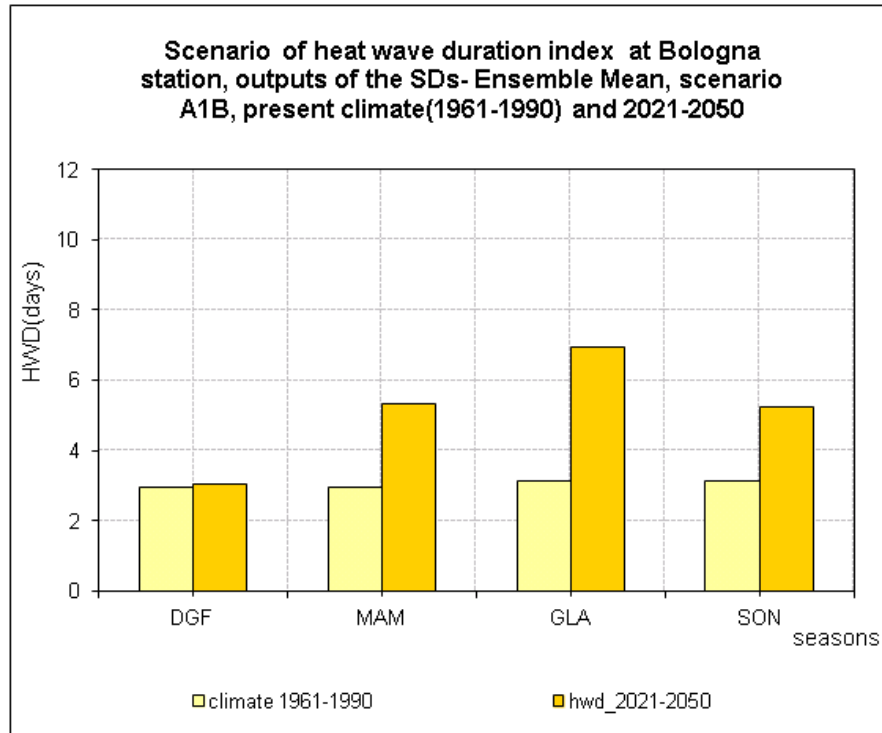


Fig. 1.3.5.4 Ensemble Mean (EM) of seasonal heat waves projected at Bologna station (CCAReg model), scenario A1B, 2021-2050 and present climate (1961-1990).

D) Conclusion

The future scenarios constructed through the statistical downscaling scheme applied to several GCMs show a possible increase in the seasonal minimum and maximum temperature over Bologna, around 2°C over the period 2021-2050 with respect to 1961-1990. The signal is more intense during summer (around 2.5°C the central moment of the distribution) when an increase of the frequency of heat waves is projected. The results are in agreement with those obtained by the regional climate models (Van der Linden et al., 2009).

Acknowledgement

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Chapter 2

Assessment indication and gold standard

Gold Standard for UHI measurements and introduction of UHI webdatabase and Atlas

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Abstract Choosing appropriate measurement sites for further investigation is one of the crucial points in determining the UHI intensity. To obtain comparable values among different cities we should use measurements obtained in similar circumstances. In the context of the deployment of an urban climate network, this guideline contains recommendations for meteorological measurement and data processing for data users who are not professionals in the field of climate measurement in urban environments. This paper presents a classification of urban measuring sites, lists steps for choosing representative stations, and provides standardized methods developed for urban climate stations and network design. Finally, these standardized approaches and guidelines are useful for making recommendations for the future deployment of urban climate networks. The final parts include the new communication and data transmission techniques for urban observation networks.

Keywords urban climate observation, Local Climate Zone, urban site location, exposure of instruments, metadata, data management

Introduction

Before any type of standard recommended by standardization committees is employed in practice, the following points should be emphasized:

- The application of standards is not compulsory.
- Obeying standards is usually voluntary.
- These statements are supplied as recommendations and suggestions during the investigation and studying of urban climate.

The original aims in elaborating these guidelines were:

- to review the current status of urban observations and the establishment of urban meteorological networks ;to identify sampling infrastructures to be developed in urban areas;
- to provide a reference system for cities which lack a monitoring network but intend to deploy one;
- to demonstrate a prototype for a new monitoring system that is already operational.

Any city operating measurement sites for UHI detection is strongly encouraged to adopt the recommendations of the Gold Standard to its measurement and evaluation systems in order to obtain better coverage of UHI phenomena over the city.

Finally, these standardized approaches and guidelines are useful for making recommendations for the future deployment of urban climate networks. The final chapter includes the new communication and data transmission techniques for urban observation networks.

In this era, environmental observations are not the sole privilege of hydrological and meteorological institutions. There are several examples of different networks working together, with the output of each supplementing the others. It remains true that reliable data are needed; networks and measuring systems need to meet various requirements (for example ISO 2009:2008). Complying with these regulations and laws can make the operation of such measuring systems more expensive.

The description presented below shows that any kind of observation requires a significant financial effort, technical background, and maintenance capacity for any agency, municipality, or national institution undertaking this activity. New in-situ observatories based on citizens' personal devices reduce investment in and running costs of in-situ observations and monitoring applications. One method called “Citizen Observatories” is based on devices such as smart phones, tablets, laptops, and social media, and it can strengthen environmental monitoring capabilities.

2.1 Concepts

The heterogeneous natural and artificial surfaces of urban environments imply that atmospheric observations require a dense measuring network to resolve the local climate adequately. In this document, the current state of urban meteorological sites and networks is shown. Afterward, this document presents suggestions for better descriptions and representations of the surroundings of stations, and it also outlines better documentation of network characteristics, standardized approaches, and recommended guidelines for urban observations to follow.

Before the deployment of a meteorological station, logistics and plans are needed. The establishment a new urban climate network requires a huge financial commitment from the developer; underscoring the need for forward-looking planning. Prior to implementation, the investigator should make efforts to find suitable meteorological sites

and instruments; determine their measurement programs; and describe the frequency of maintenance and calibration procedures required by quality assurance and quality control (QA/QC) systems for any kind of measurement.

The observation of urban climate can proceed through mobile measurements and stationary sites. Because of the relatively high cost and difficulty in siting equipment for fixed meteorological monitoring stations, their deployment and maintenance ultimately results in sparse data coverage for urban areas. In this document, recommendations are made for the operation of fixed meteorological stations and networks, which are the only way to gain sufficient, detailed information from urban regions. These observation methods can be complemented by remote sensing techniques used for interpolation, but even these do not allow for the appropriate spatial and temporal resolution or a sufficiently wide range of observed variables.

Traditionally, meteorological measurements have not been taken in urban areas but in open areas representing larger regions, as the WMO (2008) prescribed in siting synoptic measuring stations, and as it was also presented in Chapter 5 of the UHI Assessment Manual. However, on many occasions it is impossible or makes no sense to conform to these guidelines. This document recommends some principles that will help in such circumstances, even though it is not possible to anticipate all eventualities. The recommendations presented here remain in agreement with general objectives set out by the WMO (see the chapters “Siting a monitoring site” and “Exposure of instruments”). Many urban stations have been placed over short grass in open locations (parks, playing fields), and as a result they are actually monitoring an environment of the type modified rural. In many respects, the generally accepted standards for the exposure of meteorological instruments set out in WMO (2008) applies to urban sites. All details, including deviations from guidelines, should be logged thorough “metadata” (additional information about the whole network), which is essential in order to provide a data end-user with the information required to process and use the network’s data adequately.

This paper aims to provide instruction on how to obtain integrated and harmonized measurement data in relation to UHI phenomenon, by standardizing and unifying urban microclimate data. Toward these ends, the following items will be discussed:

- Defining urban climate zones
- Site placement
- Network design
- Instrumentation
- Operational definition
- Reporting of data.

Complex, morphologically heterogeneous urban environments must be studied in fine detail, so it as necessary to obtain a better understanding of weather and climate interactions and impacts in these areas. Robust planning, design, field documentation, installation, management, quality assurance (QA), and maintenance are essential parts of any successful network of sensors.

Prior to the establishment of a new monitoring network in an urban environment, the following logistical steps should be undertaken:

1. Collect information and consult with experts about the climate observations and surveying or measuring activities in advance.
2. In the planning phase, write a detailed task list. Determine the aims and tasks of the measurement program.
3. List the measurement climate elements (see the UHI Assessment Manual, Chapter 6) and define the technical requirements of measurement as range, reported resolution, required measurement uncertainty, sensor time constant, output averaging time, and achievable measurement uncertainty (see the UHI Assessment Manual, Chapter 7, for a detailed description).
4. Process orders to obtain the most appropriate equipment.
5. Choose the sites and install the equipment.
6. Prepare sensors and data logging and metadata files (see the UHI Assessment Manual, Chapter 8, for a description of metadata).
7. Record the calibration and maintenance requirements of the climate network. These steps are summarized in Fig. 2.1. After their implementation, reliable climate data will be available for the further evaluation and statistical analysis of climate signals in a given urban area.

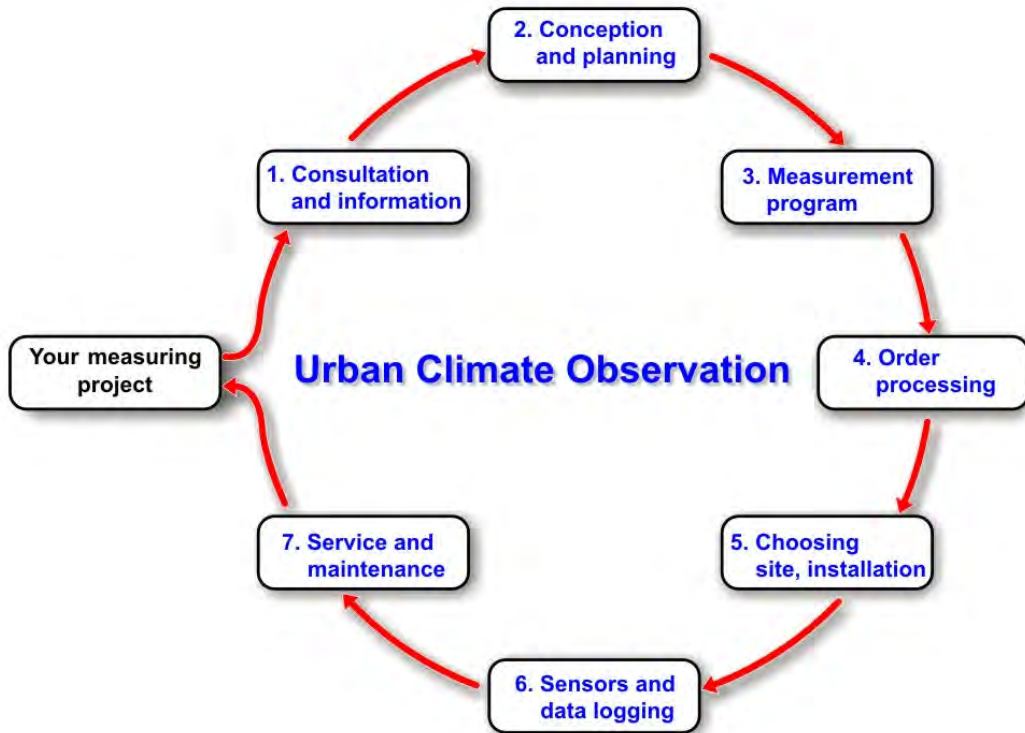


Fig. 2.1 Process chain for measurement project planning, management and service

The original aims in elaborating these guidelines were

- to review the current status of urban observations and the establishment of urban meteorological networks;
- to identify sampling infrastructures to be developed in urban areas;
- to provide a reference system for cities which lack a monitoring network but intend to deploy one;
- to demonstrate a prototype for a new monitoring system that is already operational.

Any city operating measurement sites for UHI detection is strongly encouraged to adopt these recommendations to its measurement and evaluation systems in order to obtain better coverage of UHI phenomena over the city.

2.2 Planning a Representative Urban Climate Station Network

The simple classification of measuring sites contains categories for urban, downtown, suburban, and rural sites. For correct and precise heat island evaluation, far more detailed descriptions of urban areas are necessary, as Stewart and Oke's method (2012) suggests applying. Local Climate Zones were introduced for characterizing the building and vegetation structures of a compact urban region.

Stewart and Oke formally defined Local Climate Zones (LCZs) as regions of uniform surface cover, structure, material, and human activity that span hundreds of meters to several kilometers in the horizontal scale. The LCZ system comprises 17 zone types at the local scale (100m to 1000m). Each type is unique in its combination of surface structure, cover, and human activity. Classification can be made on the basis of built-up area (10 classes) and types of land cover (7 classes). Classification of sites into appropriate LCZs requires basic metadata and surface characterization. The zone definitions provide a standard framework for reporting and comparing field sites and their climate observations.

LCZs are a widely used classification system. It provides useful information for

- defining UHI magnitude,
- establishing comparable values originating from different sites,
- modeling climate and analyzing temperature,
- detecting features that influence microclimates.
- Determination of LCZs means defining urban areas characterized by the same structure, a similar built-up ratio, and relatively similar building heights. Bordering is essential for finding ideal and representative sites for urban climate observation. Typically, a three-step process is suggested to users when classifying field sites into one of the 10 LCZs:

Step 1: Collect site metadata; namely, survey the surface cover of the region. The best way is to visit the field sites personally in order to survey and assess the local horizon, building geometry, land cover, surface wetness, surface relief, traffic flow, and population density. If a field visit is not possible, secondary sources of site metadata include aerial photographs, land/cover/land use maps, and satellite images (e. g., Google Earth and published tables of property values, such as Davenport categories).

Step 2: Define the source area of measurements. The thermal source area or footprint for a temperature measurement is the total surface area "seen" by the sensor. Sources will include upwind buildings, the walls and floor of an upwind street, and perhaps a branching network of more distant street canyons.

Quantifying the surface properties for field sites and source areas located on or near the border of two or more zones is problematic. It is better to place the sensor where it can sample from a single LCZ. When this is not possible, temperature data retrieved from that site should be stratified first according to wind direction, then to LCZ. A site with a split classification is less ideal for heat island studies because changes in airflow and stability conditions

interfere with the relation between surface form/cover and air temperature. It is recommended that transitional areas be avoided when siting meteorological instruments (Oke, 2008).

Step 3: Select the LCZ. Metadata collected in Step 1 should lead users to the best, although not necessarily exact, match of their field sites with LCZ classes. Metadata are unlikely to match perfectly with the surface property values of one LCZ class. If the measured or estimated values align poorly with those in the LCZ datasheets, the process of selecting a best-fit class becomes one of interpolation rather than straight matching. Users should first look to the surface cover fractions of the site to guide this process. If a suitable match still cannot be found, users should acknowledge this fact and highlight the main differences between their site and its nearest equivalent LCZ.

Updating LCZ designations is crucial for all sites, particularly those used in long-term studies. Sites located on the edges of cities where urban growth and environmental changes are rapid, or in the cores of cities where land re-development and large scale greening projects are taking place, should be surveyed and classified annually. For sites used in mobile or short-term stationary surveys; the frequency of updates is dedicated largely by day-to-day variations in weather and soil moisture.

2.3 Exposure of instruments

There are numerous possibilities for setting up urban climate stations, such as screen level, on a roof, in a street canyon, which vary depending on the LCZs where they are situated.

A primary survey of study area can document the presence of obstacles close to the measurement site. The main discrepancies are caused by unnatural surfaces and shading:

- a) Obstacles around the screen influence the irradiative balance of the screen. A screen close to a vertical obstacle may be shaded from the solar radiation, “protected” against the night radiative cooling of the air by receiving the warmer infrared radiation from this obstacle, or otherwise influenced by reflected radiation.
- b) Neighboring artificial surfaces may heat the air. Reflective surfaces (e. g., buildings, concrete surfaces, car parks) and water sources (e. g., ponds, lakes, irrigated areas) should be avoided.

Each climate parameter being measured at a site carries its own considerations. The following requirements represent a good urban observation station, acceptable for air temperature and humidity measurements (Figure 2.2):

- a) measurement point situated at least 10m from artificial heat sources and reflective sources (buildings, concrete surfaces, car parks, etc.) or expanses of water (unless indicative of the region) occupying
 - i) less than 50% of the surface within a circular area of 10m around the screen,
 - ii) less than 30% of the surface within a circular area of 3m around the screen.
- b) station away from all projected shade when the sun is higher than 20°.
- c) station within ground covered with natural and low vegetation (< 25cm) representative of the region.

Within these guidelines, the recorded temperature and humidity data contain additional uncertainty of up to 2°C compared to a station placed on flat, horizontal land surrounded by open space.

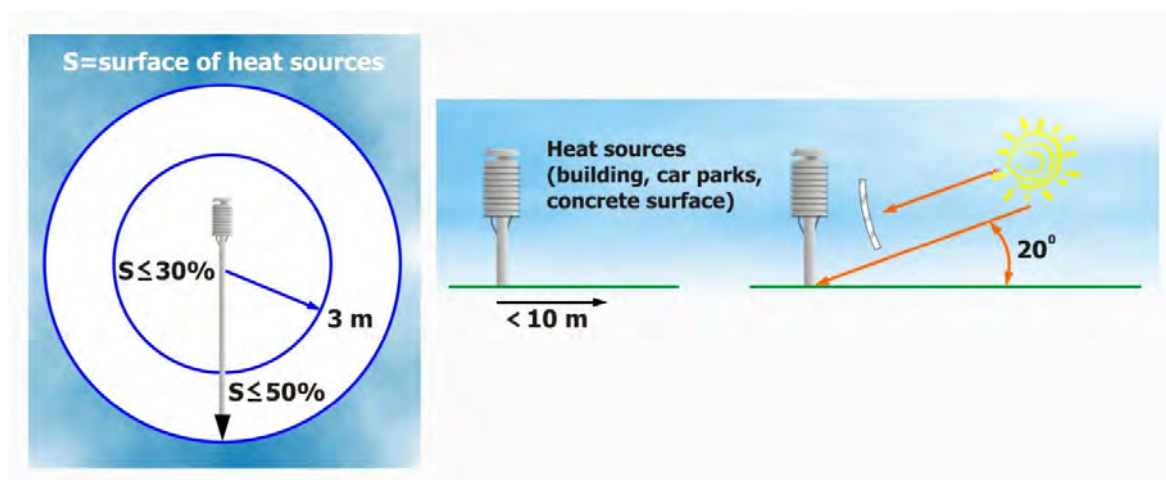


Fig. 2.2 Suitable location of air temperature and humidity sensors in urban environments, based on WMO Guide, 2008.

The choice of a site for representative precipitation measurement in an urban area should fulfill the following minimum requirements (Fig. 2.3):

- The land is surrounded by an urban area, on a slope of less than 30° .
- Possible obstacles must be situated at a distance greater than one half the height of the obstacle. An obstacle represents an object with an angular width of 10° or more.

By following these guidelines, uncertainty of precipitation measurements remains within a 25% deviation from standard observations taken in a flat and open area.

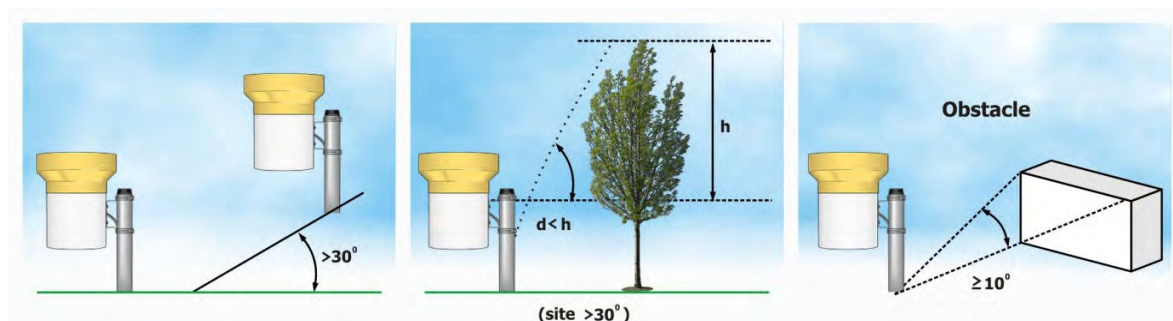


Fig. 2.3 Representative precipitation measurement in an urban area, based on WMO Guide, 2008.

- c) Where numerous obstacles (buildings, trees, etc.) are present, it is recommended that sensors be placed above the average height of the obstacles to minimize the influence of adjacent obstacles. A measuring mast can serve as a reliable location (Fig. 2.3.4).
- d) The mast should be placed away from obstacles, at a distance of at least 2.5 times the height of surrounding obstacles;
- e) No obstacle with an angular width greater than 60° and a height greater than 10m should be within 40m of the mast. Single obstacles lower than 6m can only be ignored for measurements taken at 10m or above.

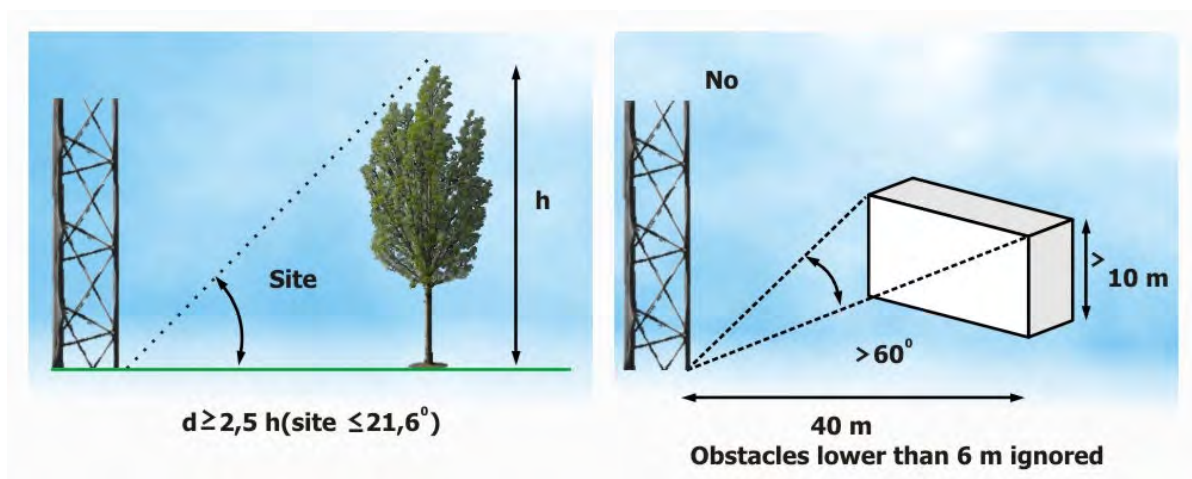


Fig. 2.4 Reliable location for measuring mast, based on WMO Guide, 2008.

In the case of measurements of global, diffuse, and direct radiation, the general rule is that close obstacles should be avoided. An obstacle is considered to be reflecting if its albedo is greater than 0.5. The reference position for elevation angles is the sensitive element of the instrument. It is recommended that shade be allowed to project into the sensor during no more than 30% of daylight hours for any day of the year (Fig. 2.5).

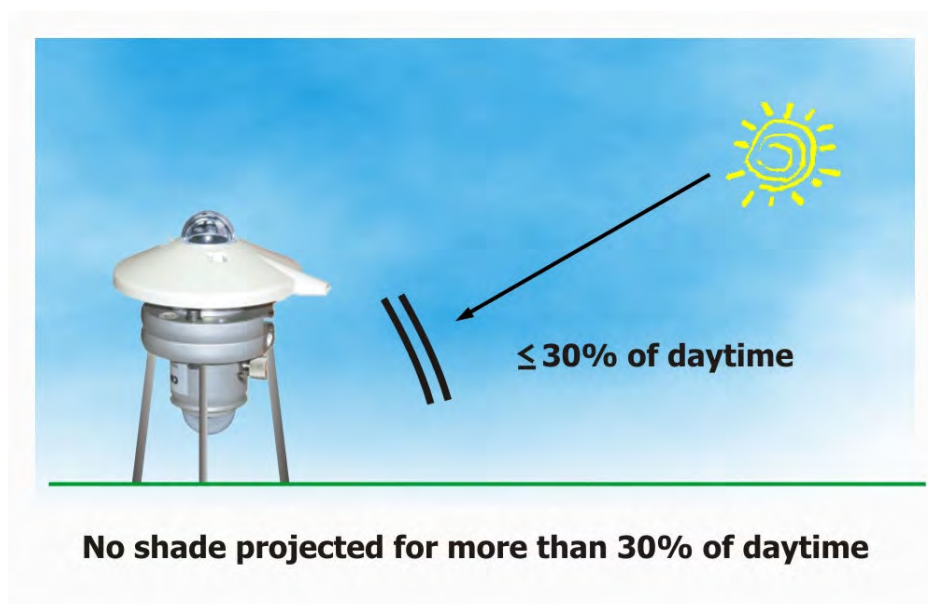


Fig. 2.5 Recommendation for representative solar radiation observation, based on WMO Guide, 2008.

If the site does not meet all the requirements above, the specific environment or application should be recorded in a metadata file. The general template of a station metadata file is presented in subchapter 2.5.

Temperature

In different LCZs, the following suggestions should be considered in finding suitable locations for air temperature measurement:

- The sensor should be relatively far from warm surfaces, walls, roads, or vehicles with hot engines, and it might receive reflected heat from glassed surfaces.
- In very densely built-up LCZs (such as LCZ 1, LCZ 2, LCZ 4, and LCZ 5) sensors should be set up 5-10m from buildings of height 20-30m, as shown in Fig. 2.6.
- Sometimes in slightly greater source areas, sensor damage can be prevented by placing the sensor away from the path of vehicles, thereby avoiding exhaust heat and dust contamination. Measurement heights of 3m or 5m are accepted as a standard.
- There is no simple, general scheme for extrapolating air temperature horizontally inside the Urban Canopy Layer (UCL).

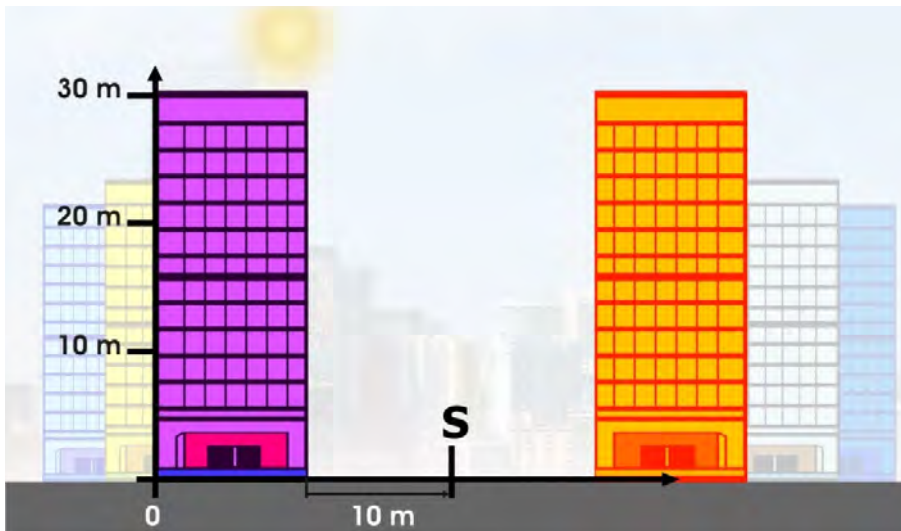


Fig. 2.6 Thermal and humidity measures on the horizontal scale in a densely built-up area.

The following recommendations are made for choosing the most reliable height for a thermometer:

- The recommended screen height is between 1.25m and 2m above ground level for urban sites (similar to non-urban stations), but it is better to allow a greater height in densely built-up areas (such as LCZ 1, LCZ 2, LCZ 4, and LCZ 5).
- In the Urban Canopy Layer there is little variation in temperature with height, while there is a discontinuity near roof level both horizontally and vertically. Consequently, if a meaningful spatial average is sought, sensors should be well above mean roof level. The recommended height is $>1.5z_H$ (where z_H is mean height of the roughness elements), so that the mixing of roof and canyon air is accomplished (see Fig. 2.7).
- For an urban environment, there is currently no standard method for extrapolating air temperature data down towards screen level (2m in height).

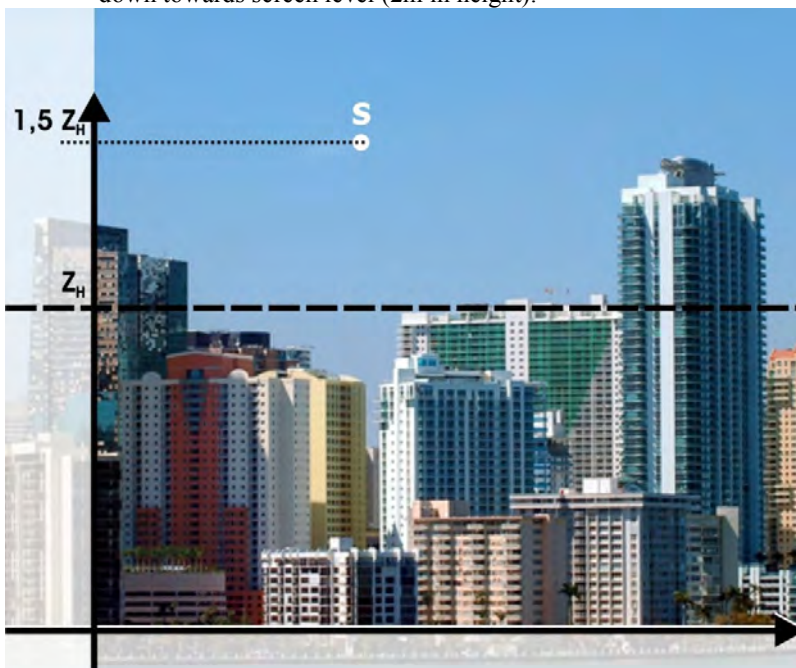


Fig. 2.7 The height scale of thermal measurements in a densely built-up area.

Other facts to consider during the placement of a thermometer in urban environments:

- Careful attention to radiation shielding and ventilation is highly recommended.
- Use of the same sensor assemblies (with/without shields and ventilation) inside a network is strongly advised in order to avoid inter-site differences.

Surface temperature is not commonly measured at urban stations; its measurement is only possible using infrared remote sensing or a downward-facing pyrgeometer, or by employing one or more radiation thermometers for which the combined field of view covers a representative sample of the urban district.

Humidity

The instruments normally used for measuring humidity can be used in urban areas. The siting and exposure of air temperature sensors presented in the previous chapter apply equally to humidity sensors in the Urban Canopy Layer and above the Roughness Sublayer (see Fig. 2.6 and Fig. 2.7). For humidity measurement, the same sensor is used as in temperature sampling. Because urban environments are far dirtier than rural sites (in terms of dust, oils, and pollutants), thermometers and hygrometers require increased maintenance and frequent service. Yearly changing and calibration are strongly advised. The provision of shielding from extraneous sources of solar and long-wave radiation is also recommended.

Wind speed and direction

Wind speed and direction are very sensitive to flow distortion by obstacles including

- effects of local relief due to hills, valleys, and cliffs,
- sharp changes in roughness or in the effective surface elevation (zd: zero-plane displacement length),
- perturbation of flow around clumps of trees and buildings,
- obstacles in the form of individual trees and buildings (Fig. 2.8),
- disturbances induced by the physical bulk of the tower or mounting arm to which the instrument is attached.

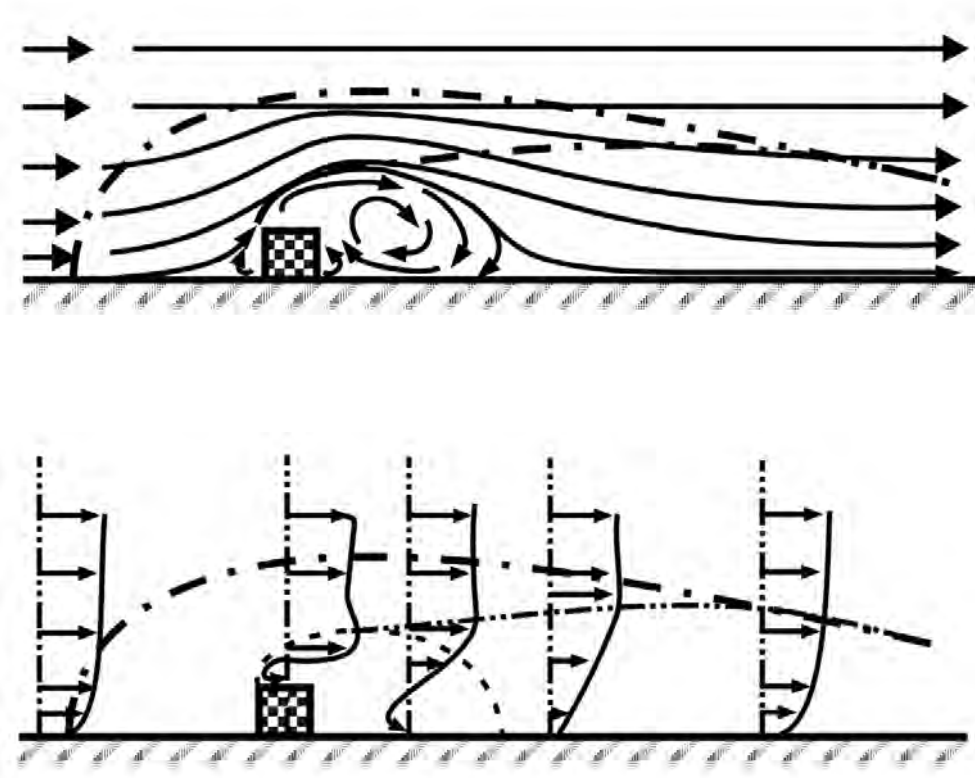


Fig. 2.8 Typical two-dimensional airflow and a vertical wind structure around a building (figures after Halitsky, 1963)

In choosing the height for wind measurement, some basic principles should be considered.

- The standard height for rural wind observations is 10m above ground, at a horizontal distance from obstructions of at least 10 times the height of the obstacle. Following this guideline is difficult in typical urban districts; where a patch of at least 100m radius would be required around 10m-high buildings and trees.
- In a densely built-up area where the effects of individual roughness elements persist, the top of roughness sublayer is about $1.5zH$, meaning that the recommended anemometer height is at least 15m if the closest buildings are 10m high.

Problems of turbulence and vortex flow, resulting from inappropriately placing anemometers behind a building, can be avoided by mounting the sensors, as shown in Figure 2.8. The recommended height for airflow detection in urban environments is summarized below, with distinctions among different LCZs:

- In urban districts with low element height and density (such as LCZ 6, LCZ 7, LCZ 8, and LCZ 9), it may be possible to use a site where the “open country” standard exposure guidelines can be met. To use the 10m height, the closest obstacles should be at least 10 times their height from the anemometer and no more than about 6m high on average.
- In more densely built-up districts (such as LCZ 1 and LCZ 2) with relatively uniform element height and density (buildings and trees), wind speed and direction measurements should be taken with the anemometer mounted on a mast of open construction at a minimum height of 1.5 times the mean height of the elements.
- In urban districts (such as LCZ 4 and LCZ 5) with scattered tall buildings, the recommendations are as in previous point, but with special attention toward avoiding the wake zone of the tall structures.

According to Harman I.N., 2003, setting up an urban climate station in a street canyon requires consideration of different airflows, depending on canyon sizes. Horizontal air currents above the roof level create eddies, caused by flow blockage from buildings. If the street canyon is wide enough, the current system within the street canyon consists of two parts: one part that has closed circulation, and another part which is blown through. The ratio of these two, easily discernible parts depends on the buildings and the width of the street.

If the width of the street is at least three times the height of the buildings (Fig. 2.9/a), then the eddying air currents have no effect whatsoever on the neighboring building, and the street canyon has free airflow.

If the width of the street is gradually decreased within the model, then the closed eddy will dominate the entire width of the street, resulting in the characteristic feature that the direction of the prevailing wind blowing at street level is the opposite of the direction of the currents at roof level (Fig. 2.9/b).

If the width of the street is narrowed further, so that the ratio of the height of the buildings and the width of the street exceeds $2/3$ (Fig. 2.9/c), then the entire street canyon will be characterized by a closed eddy that prevents airing through, causing hot air to become trapped and allowing air pollutants produced by motor vehicles to accumulate.

a) H/W ratio is $1/3$

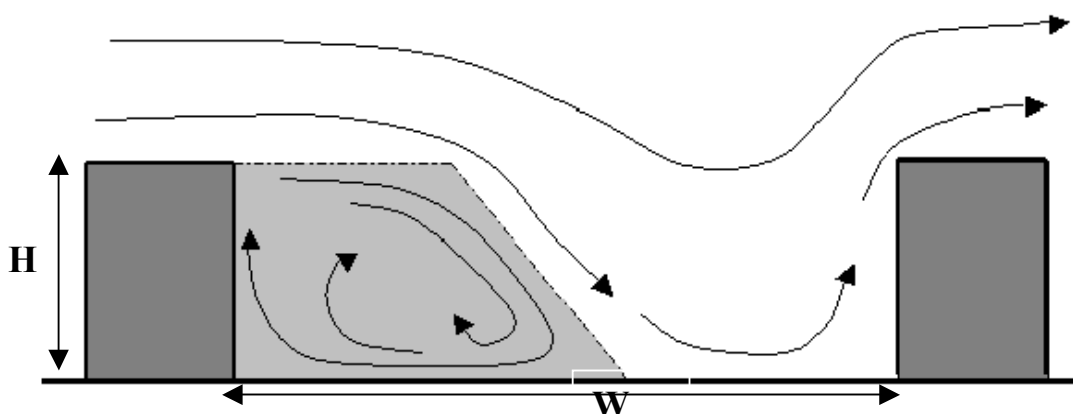


Fig. 2.9/a

b) H/W ratio around 1/2

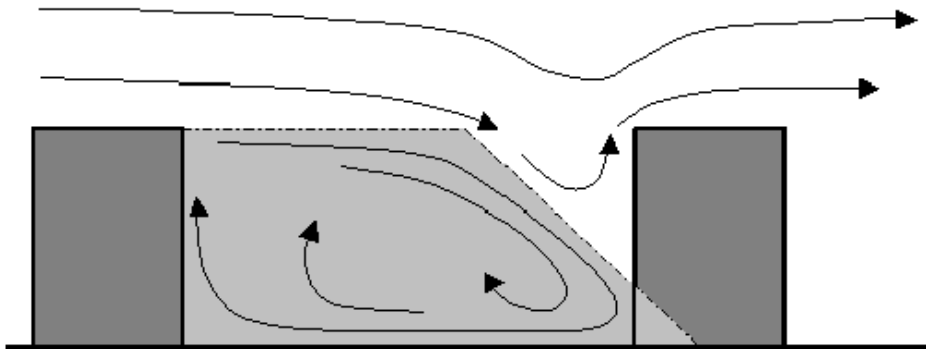


Fig. 2.9/b

c) a narrow street

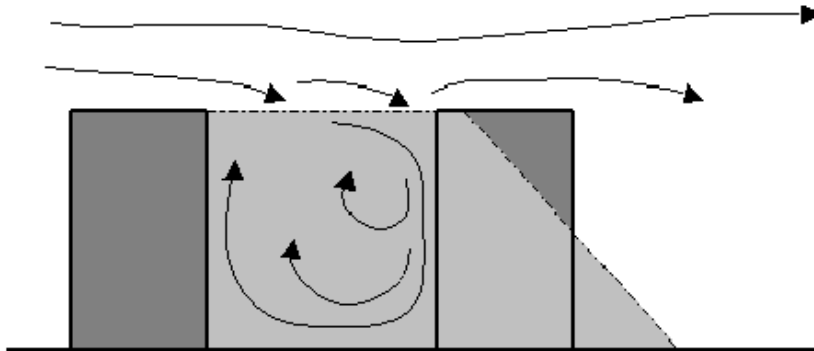


Fig. 2.9/c Typical air flow in a street canyon

Precipitation

In urban areas, instruments and methods for the measurement of precipitation are the same as an open site. The measurement of precipitation (such as rain or snow) is very susceptible to changes in airflow in the vicinity of the measurement.

In urban environments, measurement errors are associated with the following main causes:

- the interception of precipitation during its trajectory to the ground by nearby collecting surfaces, such as trees and buildings,
- hard surfaces near the gauge which may cause splash-in into the gauge, and over-hanging objects which may drip precipitation into the gauge,
- the spatial complexity of the wind field around obstacles in the LCZ, causing significant localized concentration or absence of rain- or snow-bearing airflow,
- the gustiness of the wind in combination with the physical presence of the gauge itself, causing anomalous turbulence around it and leading to under- or over-catch.

In open country, standard exposure requires that obstacles should be no closer than two times their height. In some ways, this guideline is less restrictive than for temperature, humidity, or wind measurements. However, in the UCL the turbulent activity created by flow around sharp-edged buildings is more severe than that around natural obstacles, and it may persist for greater distances in their wake. Again, the highly variable wind speed and direction encountered on the roof of a building make rooftops sites to be avoided.

With regard to precipitation gauges in urban areas, the following guidelines are recommended:

- Gauges should be located in open sites within the city, where the standard exposure criteria can be met (for example, playing fields, open parkland with a low density of trees, urban airports).
- Gauges should be located in conjunction with wind instruments if a representative exposure for them is found.
- Gauges should not be located on the roofs of buildings unless they are exposed at a sufficient height to avoid the wind envelope of the building.
- The measurement of snowfall depth should be taken at an open site or, if made at developed sites, a large spatial sample should be obtained to account for the inevitable drifting around obstacles. Such sampling should include streets oriented in different directions.
- Dew, ice, and fog precipitation also occurs in cities and can be of significance to the water budget, especially for certain surfaces. These forms of precipitation may also be relevant to applications such as plant diseases, insect activity, road safety, and finding supplementary sources for water resources.

Solar radiation

Solar radiation data are very useful inputs for several climate variables, such as atmospheric stability; daytime cloud activity; turbulence statistics; the fluxes of momentum, heat, and water vapor; determination of mixing height; and pollutant dispersion and models. The data can also be used to represent daylight levels in buildings and pedestrian comfort. Adding solar radiation measurements to an automatic station is very simple, relatively inexpensive, and highly recommended.

Solar radiation measurement sites are often located in rural or remote locations specifically to avoid the aerosol and gaseous pollutants of cities that “contaminate” their records. For stations located in built-up areas, only incoming solar (global) radiation is likely to be measured; neither incoming long wave nor any fluxes with outgoing components are monitored. All short- and long-wave fluxes are affected by the spatial properties of the atmosphere and the surface of cities, and the same is true for the net all-wave radiation balance that effectively drives the urban energy balance.

The placement of solar radiation sensors on the top of high building is a widely used and preferable practice that avoids horizon obstructions.

Instrument	Parameter to be measured
Pyrheliometer	Direct solar radiation
Pyranometer	a) Global radiation b) Sky radiation c) Reflected solar radiation
Spectral pyranometer	Global radiation in broadband spectral ranges
Net pyranometer	Net short-wave radiation
Pyrgeometer	a) Upward long-wave radiation (downward looking) b) Downward long-wave radiation (upward looking)
Net pyrradiometer	Net long-wave radiation
Net radiometer	Total radiation balance

Tab. 2.1 Meteorological radiation instruments used in a network.

The principal exposure requirement for monitoring direct solar radiation is freedom from obstructions to the solar beam at all times and seasons of the year. Furthermore, the site should be chosen so that the incidence of fog, smoke, and airborne pollution is as typical as possible for the surrounding area.

On the one hand, incoming solar radiation is a fundamental forcing variable of urban climate, so its measurement has a high priority in the establishment of an urban automatic station, where its assessment is quite simple and relatively inexpensive. The instruments for measuring incoming radiation fluxes are listed in Table 1. The following recommendations should be observed when pyranometers and other incoming flux sensors might be installed:

- Mount the sensor at some height.
- Choose a site free of vibration, such as a stable platform or the roof of a tall building (often ideal).
- Make sure that the site is free from any obstructions (buildings, hills, towers, trees).
- Avoid excessive reflection from very light-colored walls above the local horizon.
- In polluted environments, upper domes should be cleaned on a daily basis.

On the other hand, the reflection of solar radiation, the emission and reflection of long-wave radiation from the underlying surface, and the net results of short-, long- and all-wave radiant fluxes are seldom and poorly observed in urban environments. Difficulties in measuring include finding a representative area of urban surface. In cases of standard exposure, the sensor height is 2m over a short grass surface. Over an urban area, greater height is necessary to be representative for the given LCZ. Consider a radiometer at a height of 20m (at the top of a 10m mast mounted on a 10m- high building) in a densely developed district (such as LCZ 1, LCZ 2, LCZ4, or LCZ 5). The radiometer faces downward toward the surface. In this case, the 90% source area has a diameter of 120m at ground level, which might be sufficient to detect surface structures involving roofs, walls, roads, and ground surface that are in the sun or in shade. It is generally recommended that downward-facing radiometers be placed at least height of $2z_H$, and preferably higher. The radiative properties of the immediate surroundings of the radiation mast should be representative of the urban district of interest.

The backs of inverted sensors are exposed to solar heating, which can be prevented by shielding and insulation. In finding a suitable height for a measuring mast, the maintenance and cleaning of instrument domes should be taken into account to avoid any difficulties.

2.4 Measurement programs in urban environments

The meteorological elements to be measured, in order of priority, are:

- Air temperature
- Surface temperature (natural, artificial)
- Soil temperature (optionally)
- Air humidity
- Wind speed and direction, mean wind profile
- Precipitation
- Radiation, incoming fluxes, outgoing and net fluxes, sunshine duration
- Visibility, meteorological optical range (MOR)
- Evaporation (optionally)
- Soil moisture (optionally)
- Atmospheric pressure (if there is no synoptic station in the vicinity)
- Cloud cover
- Present weather.

Operational measurement uncertainty requirements and instrument performance for standard near surface meteorological measurements are summarized in WMO Guidance, 2008. Among the technical parameters, it is high-

ly advisable to study the accuracy requirements for the following parameters before planning a new meteorological site: range, reported resolution, mode of measurement/observation, required measurement uncertainty, sensor time constant, output averaging time, and achievable measurement uncertainty. In the case of meteorological elements, the technical requirements recommended for urban climate meteorological observations are listed in Tab 2.2. In any case, a description of measurement techniques, sensors characteristics, sampling procedures, calibration, and maintenance requirements are published in the user's guide or manual of each sensor to be set up. Fig 2.10 depicts a well-equipped urban meteorological and air quality station.

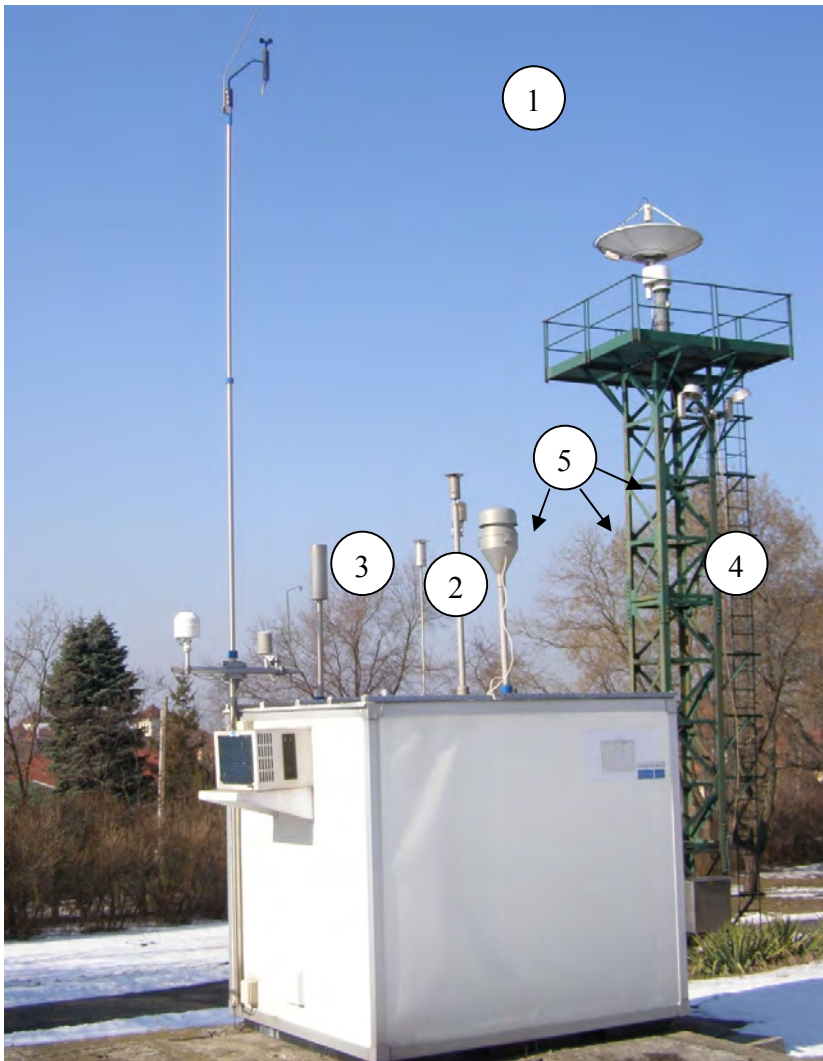


Fig. 2.10 Example of an urban monitoring station; meteorological sensors: wind (1), temperature (2), global solar radiation (3), precipitation (4), air quality (5 - gas and aerosol samplers)

Variable	Range	Reported resolution	Mode of meas./obs.	Required measurement uncertainty	Sensor time constant	Output averaging time	Achievable measurement uncertainty	Remarks
1. Temperature								
1.1 Air temperature	-80-+60°C	0.1K	I	0.3K for =-40°C	20 s	1 min	0.2 K	Achievable uncertainty and effective time constant may be affected by the design of thermometer solar radiation screen. Time constant depends on the airflow over the sensor.
1.2 Extremes of air temperature	-80-+60°C	0.1K	I	0.3K for =-40°C 0.3K for =-40°C 0.3K for =-40°C	20 s	1 min	0.2 K	
2. Humidity								
2.1 Dew-point temperature	-80-+35°C	0.1K	I	0.1K	20 s	1 min	0.5 K	Wet-bulb temperature (psychrometer)
2.2 Relative humidity	0-100%	1%	I	1%	20 s	1 min	0.2 K	If measured directly and in combination with air temperature (dry bulb). Large errors are possible due to aspiration and cleanliness problems.
					40 s	1 min	3%	Solid state sensors may show significant temperature and humidity dependence.

3. Atmospheric pressure		0.1 hPa		0.1 hPa	20 s	1 min	0.3hPa 0.2hPa	Both station pressure and MSL pressure. Measurements uncertainty seriously affected by dynamic pressure due to wind if no precautions are taken. Inadequate temperature compensation of the transducer may affect the measurement uncertainty significantly. Difference between instantaneous values
3.1 Pressure	500-1080 hPa	I	I	0.2 hPa				
3.2 Tendency	Not specified	I	I	0.1 hPa				

Variable	Range	Reported resolution	Mode of meas./obs.	Required measurement uncertainty		Sensor time constant	Output averaging time	Achievable measurement uncertainty	Remarks
4. Clouds									
4.1 Clouds amount	0/8-8/8	1/8	I	1/8	n/a			2/8	Period (30 s) clustering algorithms may be used to estimate low cloud amount automatically.
4.2 Height of cloud base	0 m-30 km	10 m	I	10 m for ≤ 100 m 10% for > 100 m	n/a			~10 m	Achievable measurement uncertainty undetermined because no clear definition exists for instrumentally measured cloud base height (e.g. based on penetration depth or significant discontinuity in the extinction profile).
5. Wind									Significant bias during precipitation.
5.1. Speed	0-75 m s^{-1}	0.5 m s^{-1}	A	0.5 m s^{-1} for $\leq 5 \text{ m s}^{-1}$	Distance constant 2-5 m	0 1	and/or 10 min	0.5 m s^{-1}	Average over 2 and/or 10 minutes. Non-linear devices. Care needed in design of averaging process. Distance constant is usually expressed as response length. Averages computed over Cartesian components (see WMO Guide 2008 Part III, Chapter 2, section 2.6)
5.2. Direction	0-360°	1°	A	5°					Highest 3 s average should be recorded.
5.3. Gusts									
6. Precipitation									
6.1 Amount (daily)									Quantity based on daily amounts. Measured uncertainty depends on aerodynamic collection efficiency of gauges and evaporation losses in heated gauges.

Variable	Range	Reported resolution	Mode of meas./obs.	Required measurement uncertainty	Sensor time constant	Output averaging time	Achievable measurement uncertainty	Remarks
6.2 Depth of snow	0-500 mm 0-25 m	0.1 mm 1 cm	T A	0.1 mm for ≤ 5 mm 2% for >5 mm 0 cm for ≤ 5 mm 5% for >20 cm	n/a	n/a		Average depth over an area representative of the observing site
7. Radiation								
7.1 Sunshine duration (daily)	0-24 h	60s	T	0.1 h 0.4 MJ m ⁻² for ≤ 8 MJ m ⁻² 5% for >8 MJ m ⁻²	20s	n/a	The larger of 0.1 h or 2% 0.4 MJ m ⁻² for ≤ 8 MJ m ⁻² 5% for >8 MJ m ⁻²	Radiant exposure expressed as daily sums (amount) of (net) radiation.
7.2 Net radiation, radiant exposure (daily)	Not specified	1 J m ⁻²	T		20s	n/a		
8. Visibility								
8.1 Meteorological Range (MOR)	10 m-100 km	1 m	I	50 m for ≤ 600 m 10% for > 600 m- ≤ 1500 20% for > 1500 m	<30s	1 and 10 min	The larger of 20 m or 20%	Achievable measurement uncertainty may depend on the cause of obscuration. Quantity to be averaged: extinction coefficient (see WMO Guide 2008, Part III, Chapter 2, section 2.6). Preference for averaging logarithmic values.
9. Evaporation								
9.1 Amount of pan evaporation	0-100 mm	0.1 mm	T	0.1 mm for ≤ 5 mm 2% for > 5 mm	n/a			

Tab. 2.2 Accuracy requirements for surface meteorological measurements Source: WMO Guide, 2008.

2.5 Site description for METADATA

Station metadata should contain the following aspects of instrument exposure:

- a) height of the instruments above the surface,
- b) type of sheltering and degree of ventilation for temperature and humidity,
- c) degree of interference from other instruments or objects (masts, ventilators),
- d) microscale and topoccale surroundings of the instrument, in particular
 - i. the state of the enclosure's surface, influencing temperature and humidity,
 - ii. nearby major obstacles (buildings, fences, trees) and their size,
 - iii. the degree of horizon obstruction for radiation observations,
 - iv. surrounding terrain roughness and major vegetation, influencing the wind,
 - v. all topoccale terrain features, such as small slopes, pavements, or water surfaces,
 - vi. Major mesoscale terrain features, such as coasts, mountains, or urbanization.

The survey of each site should be reviewed periodically, as environmental circumstances can change over a period of time. A systematic yearly visual check is recommended: If some aspects of the environment have changed, a new site description document should be included in the metadata file. A complete update of the site should be undertaken at least every five years.

The natural relief of the landscape can be disregarded if it is sufficiently distant (>1km). A method of judging if the relief is representative of the surrounding area is to consider whether a move of the station by 500m changes the LCZ obtained. If the answer is no, the relief is a natural characteristic of the area and is not taken into account.

One general requirement that cannot be kept at many urban sites is the distance from obstacles, namely that the site should be located well away from trees, buildings, walls, or other obstructions. Instead, it is recommended that the urban station be centered in an open space where the surrounding aspect ratio (zH/W) is approximately representative of the locality (see the aspect ratio of an LCZ from the datasheets of the given area).

The full and accurate documentation of station metadata is essential for the evaluation of measurements. Using Google Earth or ESRI ArcView to map the locations of meteorological stations is one of the most frequently used options. Metadata could include maps, sketches, aerial photos, compass surveys, or screens with a fisheye lens for describing the geographical features of a station, if they are available. An example of a documentary file for one of the UHI monitoring stations in Warsaw (at the city centre - Twarda) is given in Tab. 2.3.3. An example of visualization files of the surroundings of the Twarda observation site is presented in Fig. 2.3.11.

Number of station	II
Station name	UW
Address	Warszawa, ul. Twarda 51/55
Geographical coordinates	52°13'42,7 N, 20°59'37,8 E
Observed elements	T, RH, prec, UV, Kglob, Kref, DD/FF
Period of observation	2001-2012
Time resolution	10 min
Function of surrounded area	Research services/ residential
Settlement intensity	Very dense, multi floor
Number of floors	6-10
Horizon limitation (%)	65
Ground surface	Artificial (partially clay)
Ground water depth	Not applicable
Sewage system	Yes

Tab. 2.3 Example of a documentary file for the urban station shown on Fig. 2.10

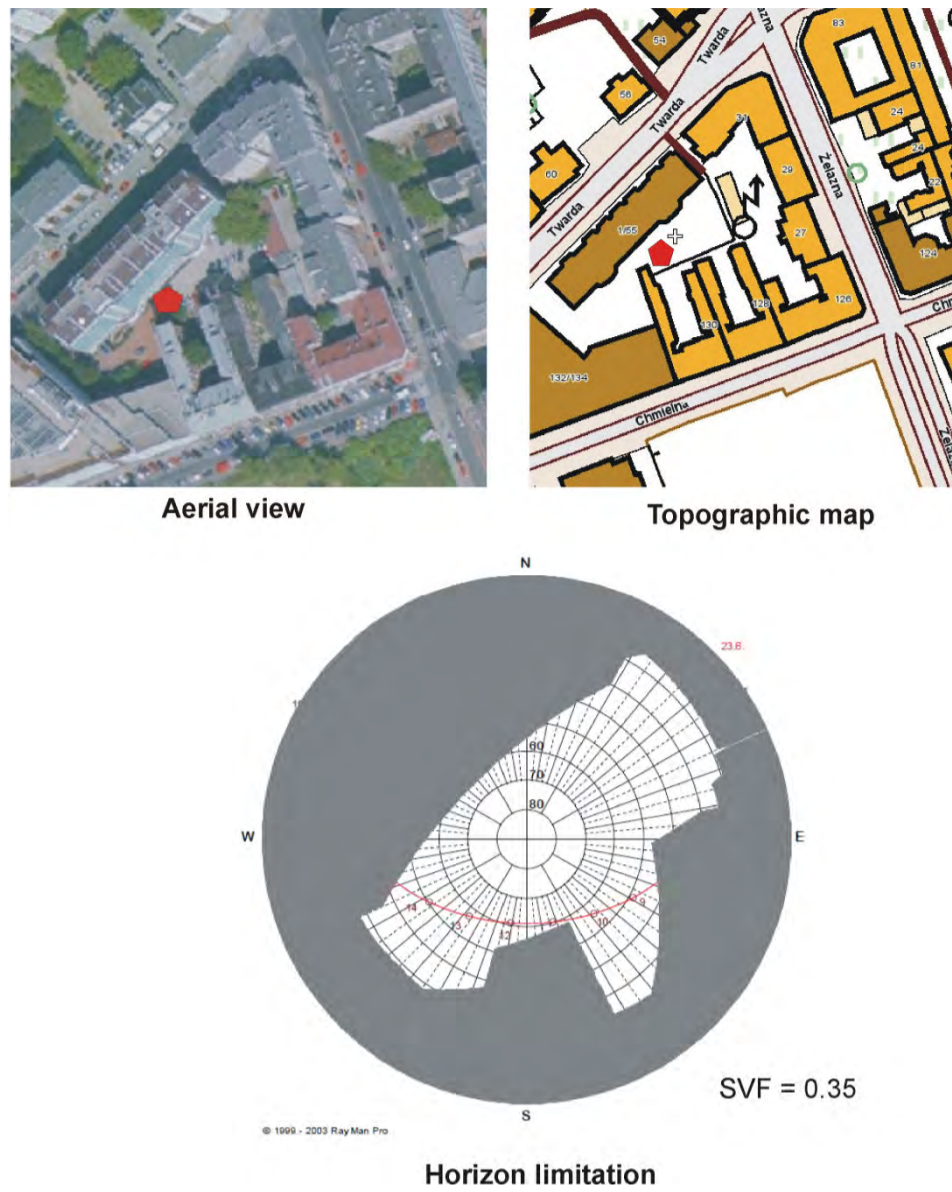


Fig. 2.11 Example of visualization documentary materials for the surroundings of an urban station located at Twarda Street in downtown Warsaw

2.6 Data transmission and data management

Communication, an essential component of any network, consists of the data flow from the sensor to initial analysis, data management, data display, and usage, jointly termed the “cyberinfrastructure” (Hart and Martinez, 2006). This infrastructure consists of computer systems, instrumentation, data acquisition, data storage systems and repositories, visualization systems, management services, and technicians, all linked by software and communication networks (Esterin et al. 2003; Brunt et al., 2007). The communication urban climatological monitoring network consists of four main segments: data collection, data management, data display, and data usage.

The majority of weather installations work on a “star” network, relaying information back to the central host server over the Internet via a wired Ethernet connection.

Urban areas are particularly well placed to utilize wireless technology, as there is an increasing number of municipal wireless access points in urban areas, allowing almost complete coverage in most towns and cities. Hence, with the appropriate permissions granted, these existing municipal wireless networks (open access or subscription wireless access points) can be utilized to relay data from sensors to the host server.

Recently developments in the miniaturization of electronics have produced advances in communications and computing power, with environmental sensors becoming more innovative, reliable, compact, and inexpensive as a result. These advances provide increased potential for urban networks of meteorological sensors, which may now be more numerous and densely spaced, with vastly improved temporal collection and rapid data transmission. The new generation of atmospheric observation networks will permit new insights into urban atmospheric processes.

The options available for powering sensor networks depend on the location of the sensors, the specific power requirements, and the nature of equipment involved. All short- and long-wave fluxes are affected by the special properties of the atmosphere and the surfaces of cities, and the same is true for the net all-wave radiation balance that effectively drives the urban energy balance (Oke, 1988). All of the instruments of radiation measurements, their calibration, the data correction, and most of the field methods are the same for urban environments as for open country sites.

The calibration of equipment and instruments during intercomparison periods is essential to ensure the quality of the data. Sensor networks frequently contain low-cost, nonstandard sensors, and as such all equipment needs to be tested against a traceable “standard” instrument. Ideally, equipment should be calibrated at a national standards and calibration lab, ensuring the reliability of results and allowing for comparisons with other equipment calibrated to the same standard. Documented quality assurance and quality control (QA/QC) procedures must be used in order to provide end-users with high-quality data. Consideration also needs to be given as to where the data are initially stored and processed (including procedures for ensuring that servers are secure and backed-up), archived long-term, and accessed by end-users.

Communication via informal methods such as websites is important for providing information to a variety of stakeholders. Many urban sensor networks have websites through which data can be visualized and downloaded on request.

Calibration processes in a laboratory imply that, under the same circumstances, parallel measurements result between sensors and reference tools. Sensor calibration should help meet the requirements described above in discussing the data quality issues facing institutions that are considering operating an automated surface weather station network. Calibration and maintenance processes should be declared in quality assurance documents for the network.

Data from urban observations should be recorded a well-defined file format, where the header of file contains the station name, observing period, observing element, and units and frequency of observations. The end-data users (researchers, general public, schools) are able to use these records for their own purposes.

2.7 Short description of the web database and UHI atlas elaboration

This report is part of Work Package 4 of the EU Central-Europe project Development and application of mitigation and adaptation strategies and measures for counteracting the global urban heat islands phenomenon. It covers deliverables 4.3.1 (set up and implementation of a virtual database, including data collection on UHI in each region) and 4.3.2 (internet-based GIS implementation of UHI maps for the territory of Central Europe and selected urban areas, namely the Central Europe UHIs Atlas). The UHI Atlas is a tool for a presentation and exploration of different factors influencing urban heat island phenomena in the Central European area.

For better understanding there are different factors influencing temperatures presented, such as the altitude, vegetation status (vegetation index), land use/cover, and settlement density (night scene image). The UHI Atlas was produced by the Anton Melik Geographical Institute ZRC SAZU.

The general goal of this report is to present the structure and characteristics of the database and atlas, with the focus on the description of the data presented.

The atlas consists of several layers in GIS environment, namely:

- UHI project partners,
- Air temperatures data for 2011 heat waves,
- Land surface temperature data acquired by satellites,
- Normalized differential vegetation index,
- Corine land cover,
- Urban atlas Land cover,
- Elevation (SRTM),
- VIIRS night scene image,
- Data from PPs.

2.7.1 UHI Atlas and database

In the fourth work package we collected the material for the database and prepared it for publication in the UHI atlas – atlas of urban heat island.

The activity was carried on with partners from Budapest (Meteo Service).

The UHI atlas was published on-line at (http://giam.zrc-sazu.si/uhi_atlas).

The database for atlas of urban heat island consists of different data:

- digital elevation model (DEM),

- normalized difference vegetation index (NDVI),
- land surface temperature data (LST),
- data on land use (Corine land cover and Urban atlas data),
- night scene image (VIIRS sensor),
- air temperature at 2 m,
- the data collected from project partners.

The database was elaborated in GIS environment using Arcgis Desktop and published online using Arcgis server programme (licence owned by GIAM ZRC SAZU).

The activity was carried on with partners from Budapest (Meteo Service) who are formally responsible for the activity.

In the first instance the test version of the atlas was prepared, the data were stored in server of a free web GIS provider (Mango maps) and is available online at http://giam.zrc-sazu.si/uhi_atlas and directly at mangomap website [http://mangomap.com/maps/6278/Urban%20Heat%20Island%20Atlas%20for%20Central%20Europe%20\(test%20version\)?admin_mode=false#zoom=5&lat=50.007739&lng=19.995117&layergroups=&isNewLayer=false&hostPermalinkEnable=false](http://mangomap.com/maps/6278/Urban%20Heat%20Island%20Atlas%20for%20Central%20Europe%20(test%20version)?admin_mode=false#zoom=5&lat=50.007739&lng=19.995117&layergroups=&isNewLayer=false&hostPermalinkEnable=false) (password: urbanheat).

The final version of the atlas is set at our server and published on-line at: <http://gismo.zrc-sazu.si/flexviewers/UHIAtlas>.

During the summer 2013 the partners provided datasets of information which are now presented on the UHI atlas. The UHI atlas website is a living document. Therefore, it is open for publishing future relevant data and results from analyses partners of the UHI project.

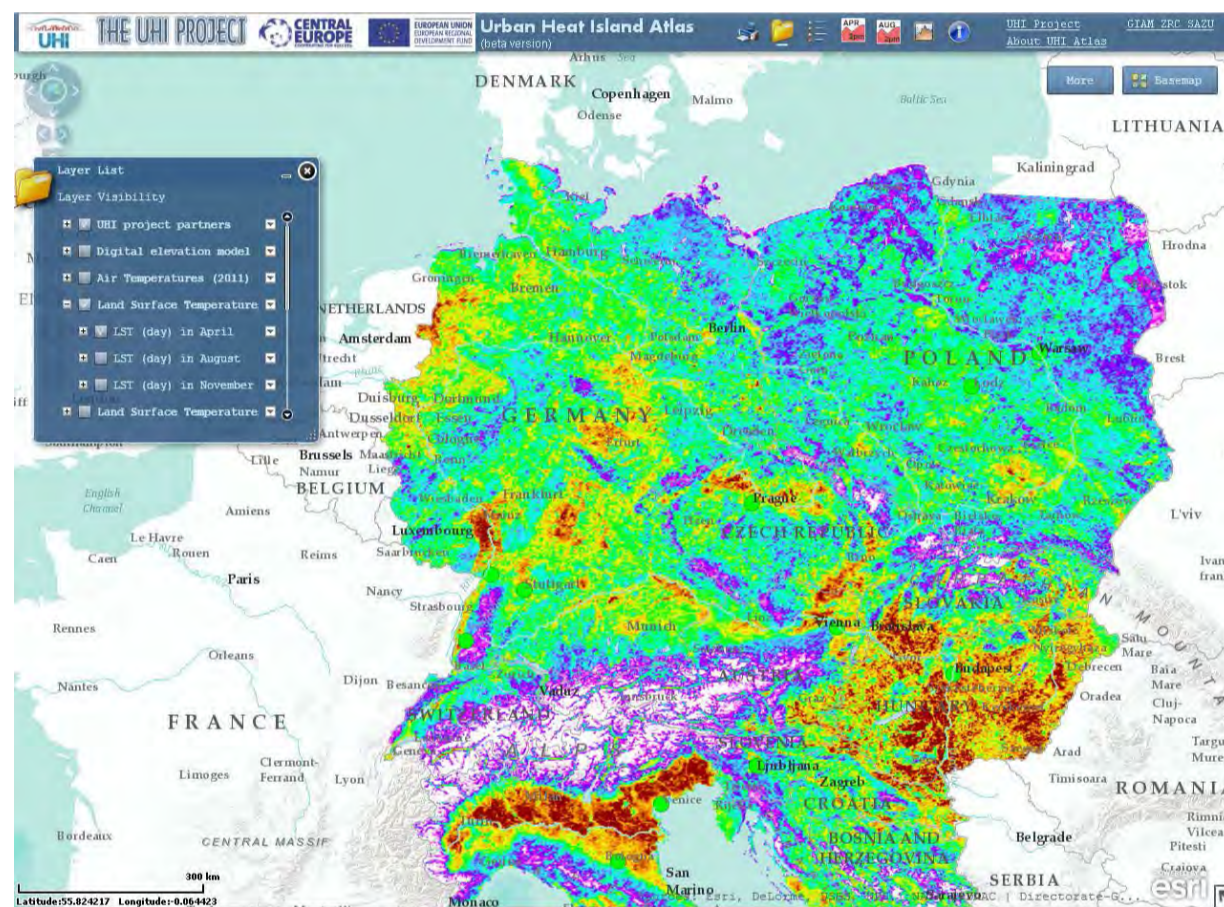


Fig. 2.12 Print screen of Urban heat island atlas for Central Europe.

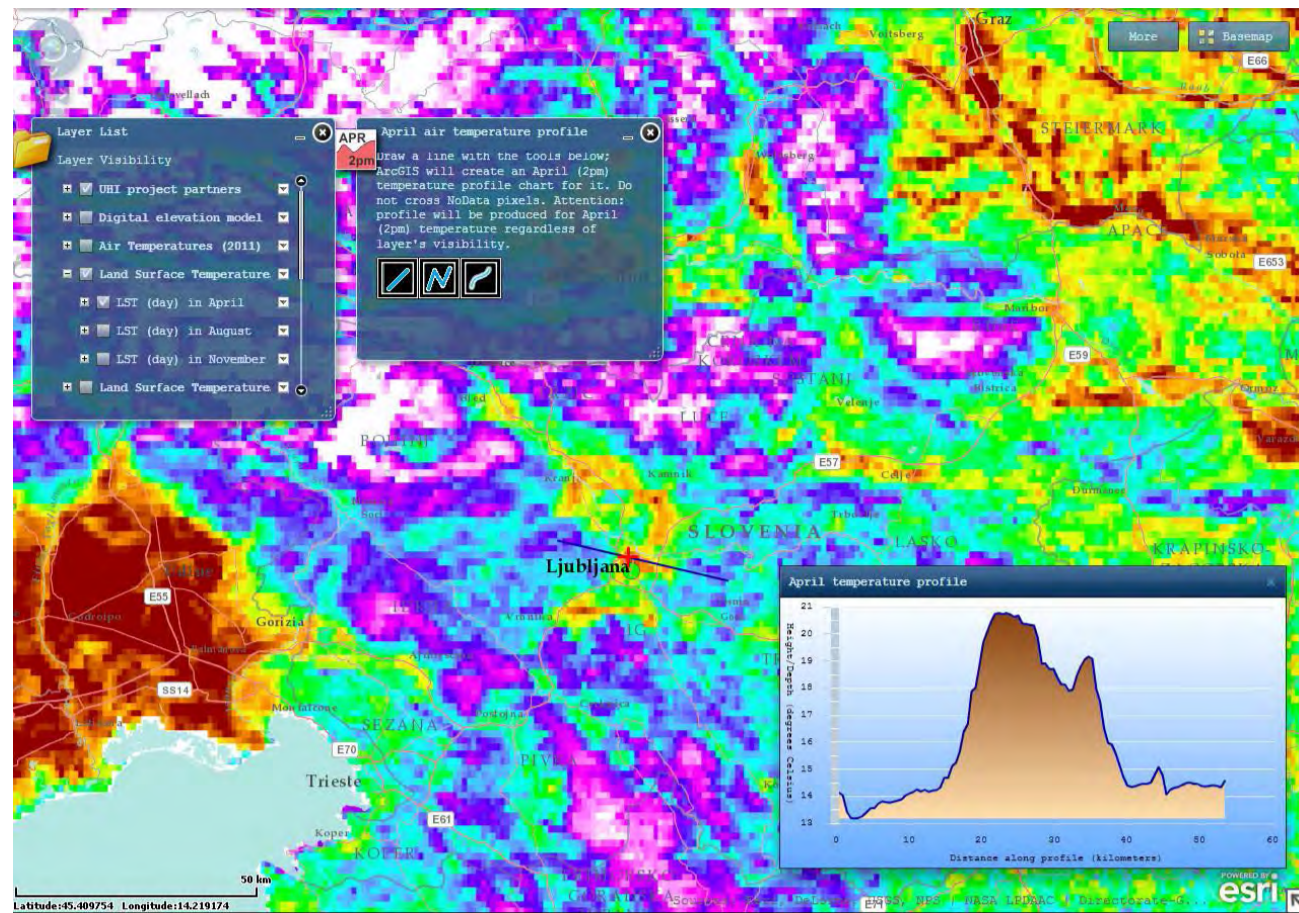


Fig. 2.13 Print screen of Urban heat island atlas. Its user friendly interface enables users to select between different layers, make profiles across April (as below) and August temperatures in Central Europe and zoom to UHI partner data.

2.7.2 Large scale data (<0,5 km resolution)

2.7.2.1 Corine Land Cover

Format: raster data (100 m) and vector data

Temporal coverage: 2006

Spatial coverage: Central Europe

Short description of Corine Land Cover

Two kind of satellites provided imagery for CLC2006 project:

- French SPOT-4&5 (60 km swath width, 20 m pixels; VIS, NIR and SWIR bands), and
- Indian IRS P6 (141 km swath width, 23 m pixels; VIS, NIR and SWIR bands).

Where to find it: <http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-2>

Data sources: The European Topic Centre on Spatial Information and Analysis. Date of delivery: April 2012

Data owners: European Environment Agency

Copyright holder: European Environment Agency (EEA)

FREELY AVAILABLE (<http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-2>)

2.7.2.2 Land Cover/Land use for cities included in project (Urban Atlas)

Format: vector data (1 : 10.000)

Temporal coverage: 2005–2007

Spatial coverage: Budapest, Vienna, Ljubljana, Prague, Stuttgart, Venice, Warszawa

Short description of Urban Atlas

The European Urban Atlas is part of the local component of the GMES land monitoring services. It provides reliable, inter-comparable, high-resolution land use maps for 305 Large Urban Zones and their surroundings (more than 100.000 inhabitants as defined by the Urban Audit) for the reference year 2006. The GIS data can be downloaded together with a map for each urban area covered and a report with the metadata.

Where to find it: European Environment Agency (<http://www.eea.europa.eu/data-and-maps/data/urban-atlas>)

Data sources: Directorate-General Enterprise and Industry (date of delivery: 15 Mar 2010 and 21 May 2010).

Data owners: Directorate-General Enterprise and Industry (DG-ENTR) and Directorate-General for Regional Policy

Copyright holder: Directorate-General Enterprise and Industry (DG-ENTR), Directorate-General for Regional Policy.

FREELY AVAILABLE (<http://www.eea.europa.eu/data-and-maps/data/urban-atlas>)

2.7.2.3 Landsat TM, ETM images (thermal band etc.)

Format: raster data (120 m, resampled to 60 m)

Temporal coverage: different examples for spring, summer and autumn

Spatial coverage: Budapest, Vienna, Ljubljana, Prague, Stuttgart, Venice, Warszawa

Short description of Landsat images

Landsat images of reflectance can show us differences among different areas (urban areas, green areas etc.). With some methods and field work measurements it is possible to define land surface temperature and air.

Where to find it: <http://earthexplorer.usgs.gov/> or other image browsers

FREELY AVAILABLE: <http://landsat.gsfc.nasa.gov/data/where.html>

The data are available in the UHI database and are not published in the UHI atlas.

Thematic mapper (TM)			Enhanced Thematic Mapper Plus (ETM+)	
Landsats 4-5			Landsat 7	
Wavelength (micrometers)	Resolution (meters)		Wavelength (micrometers)	Resolution (meters)
Band 1	0.45-0.52	30	0.45-0.52	30
Band 2	0.52-0.60	30	0.52-0.60	30
Band 3	0.63-0.69	30	0.63-0.69	30
Band 4	0.76-0.90	30	0.77-0.90	30
Band 5	1.55-1.75	30	1.55-1.75	30
Band 6	10.40-12.50	120/60*	10.40-12.50	60
Band 7	2.08-2.35	30	2.09-2.35	30
Band 8	/	/	.52-.90	15

*(The resolution is 120, but the delivered product is resampled to 60 m resolution!)

Tab. 2.4 List of bands (Landsat TM and ETM).

2.7.2.4 SRTM 90m Digital Elevation Data (DEM)

Format: raster data (3 arc second; 90 m at the equator)

Temporal coverage: 2008 (last update)

Spatial coverage: Central Europe

Short description of SRTM 90 m DEM

The SRTM digital elevation data, produced by NASA originally, is a major breakthrough in digital mapping of the world, and provides a major advance in the accessibility of high quality elevation data for large portions of the tropics and other areas of the developing world. The SRTM digital elevation data provided on this site has been processed to fill data voids, and to facilitate its ease of use by a wide group of potential users. This data is provided in an effort to promote the use of geospatial science and applications for sustainable development and resource conservation in the developing world. Digital elevation models (DEM) for the entire globe, covering all of the countries of the world, are available for

download on this site. The SRTM 90m DEM's have a resolution of 90m at the equator, and are provided in mosaiced 5 deg x 5 deg tiles for easy download and use. All are produced from a seamless dataset to allow easy mosaicing. These are available in both ArcInfo ASCII and GeoTiff format to facilitate their ease of use in a variety of image processing and GIS applications. The NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe.

Where to find it: CIAT-CSI SRTM website (<http://srtm.csi.cgiar.org>)

This data is currently distributed free of charge by USGS and is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site.

Data source (citation): Jarvis A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT), available from

<http://srtm.csi.cgiar.org>.

Data owners: see http://srtm.csi.cgiar.org/SELECTION/SRT_disclaimer.htm

Copyright holder: see http://srtm.csi.cgiar.org/SELECTION/SRT_disclaimer.htm.

2.8 Small scale data ($\geq 0,5$ km resolution)

2.8.1 MODIS NDVI images - Aqua & Terra (MYD13A2 & MOD13A2)

Format: raster data (1 km)

Temporal coverage: different examples for spring, summer and autumn (16-day average)

Spatial coverage: Central Europe

Short description of MODIS NDVI images

Vegetation indices are used for global monitoring of vegetation conditions and are used in products displaying land cover and land cover changes. These data may be used as input for modeling global biogeochemical and hydrologic processes and global and regional climate. These data also may be used for characterizing land surface biophysical properties and processes, including primary production and land cover conversion.

Global MYD13A2 data are provided every 16 days at 1-kilometer spatial resolution as a gridded level-3 product in the Sinusoidal projection. VI production is phased between Terra and Aqua acquisitions, with Terra beginning on Day 001 and Aqua beginning on Day 008.

MODIS has also variety of other products. The images are taken in different bands (Tab. 3.2.3.4).

Where to find it: <http://earthexplorer.usgs.gov/> and other image browsers

How to cite: https://lpdaac.usgs.gov/about/citing_lp_daac_and_data

Credit: NASA LP DAAC

FREELY AVAILABLE (https://lpdaac.usgs.gov/products/modis_policies)

BAND	RANGE nm	RANGE um	KEY USE
Reflected		Emitted	
1		620–670	Absolute Land Cover Transformation, Vegetation Chlorophyll
2		841–876	Cloud Amount, Vegetation Land Cover Transformation
3		459–479	Soil/Vegetation Differences
4		545–565	Green Vegetation
5		1230–1250	Leaf/Canopy Differences
6		1628–1652	Snow/Cloud Differences
7		2105–2155	Cloud Properties, Land Properties
8		405–420	Chlorophyll
9		438–448	Chlorophyll
10		483–493	Chlorophyll
11		526–536	Chlorophyll
12		546–556	Sediments
13h		662–672	Atmosphere, Sediments
13l		662–672	Atmosphere, Sediments
14h		673–683	Chlorophyll Fluorescence
14l		673–683	Chlorophyll Fluorescence
15		743–753	Aerosol Properties
16		862–877	Aerosol Properties, Atmospheric Properties
17		890–920	Atmospheric Properties, Cloud Properties
18		931–941	Atmospheric Properties, Cloud Properties
19		915–965	Atmospheric Properties, Cloud Properties
20		3.660–3.840	Sea Surface Temperature
21		3.929–3.989	Forest Fires & Volcanoes
22		3.929–3.989	Cloud Temperature, Surface Temperature

23	4.020–4.080	Cloud Temperature, Surface Temperature
24	4.433–4.498	Cloud Fraction, Troposphere Temperature
25	4.482–4.549	Cloud Fraction, Troposphere Temperature
26	1360–1390	Cloud Fraction (Thin Cirrus), Troposphere Temperature
27	6.535–6.895	Mid Troposphere Humidity
28	7.175–7.475	Upper Troposphere Humidity
29	8.400–8.700	Surface Temperature
30	9.580–9.880	Total Ozone
31	10.780–11.280	Cloud Temperature, Forest Fires & Volcanoes, Surface Temp.
32	11.770–12.270	Cloud Height, Forest Fires & Volcanoes, Surface Temperature
33	13.185–13.485	Cloud Fraction, Cloud Height
34	13.485–13.785	Cloud Fraction, Cloud Height
35	13.785–14.085	Cloud Fraction, Cloud Height
36	14.085–14.385	Cloud Fraction, Cloud Height

Tab. 2.5 List of bands (MODIS).

2.8.2 MODIS LST images - Aqua & Terra (MYD11A2 & MOD11A2)

Format: raster data (1 km)

Temporal coverage: different examples for spring, summer and autumn (8-day average)

Spatial coverage: Central Europe

Short description of MODIS NDVI images

The level-3 MODIS global Land Surface Temperature (LST) and Emissivity 8-day data are composed from the daily 1-kilometer LST product (MOD11A1&MYD11A1) and stored on a 1-km Sinusoidal grid as the average values of clear-sky LSTs during an 8-day period.

MOD11A2 & MYD11A2 are comprised of daytime and nighttime LSTs, quality assessment, observation times, view angles, bits of clear sky days and nights, and emissivities estimated in Bands 31 and 32 from land cover types

For list of MODIS bands see tab 2.3.2.

Where to find it: <http://earthexplorer.usgs.gov/> and other image browsers

How to cite: https://lpdaac.usgs.gov/about/citing_lp_daac_and_data

Credit: NASA LP DAAC

FREELY AVAILABLE (https://lpdaac.usgs.gov/products/modis_policies)

2.8.3 VIIRS night scene images

Format: raster data (750 m)

Temporal coverage: 2012

Spatial coverage: Central Europe

Short description of VIIRS (Visible Infrared Imaging Radiometer Suite)

VIIRS, a scanning radiometer, collects visible and infrared imagery and radiometric measurements of the land, atmosphere, cryosphere, and oceans. It extends and improves upon a series of measurements initiated by the Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS). VIIRS data is used to measure cloud and aerosol properties, ocean color, sea and land surface temperature, ice motion and temperature, fires, and Earth's albedo. Climatologists use VIIRS data to improve our understanding of global climate change.

Where to find it: <http://earthobservatory.nasa.gov/Features/NightLights/page3.php>

Credit: NASA's Earth Observatory, NASA

FREELY AVAILABLE (<http://earthobservatory.nasa.gov/ImageUse/>)

2.8.4 Air temperature (2 m above the ground)

Format: raster data (0.0056°)

Temporal coverage: selected periods for various seasons in 2011

Spatial coverage: Central Europe

Short description of Air temperature data

Air temperature was calculated on the basis of MODIS Land Surface Temperature (LST) by dr. Klemen Zakšek and dr. Krištof Oštir from Research Centre of the Slovenian Academy of Sciences and Arts (ZRC SAZU). For MODIS LST de-

scription see chapter 3.3.2. Calculation method is presented in the paper Estimation of daily mean air temperature from MODIS LST in Alpine areas written by Colombi, De Michele, Pepe and Rampini (2007). The paper is available here: http://e-proceedings.org/static/vol06_1/06_1_colombi1.pdf.

Where to find it: UHI Atlas

Credit: ZRC SAZU (www.zrc-sazu.si)

2.9 The data from the partners

The data provided by the partners of the UHI project and visualized in the UHI atlas consist of several different data layers and present different aspects of urban heat island phenomena and urban heat island influencing factors, such as the ones presented below. The database has been regularly updated by the UHI partnership and it could be updated until end of the project.

2.9.1 The case of Bologna and Modena

- Meteorological stations in the Bologna and Modena area,
- Air quality monitoring system in the Bologna and Modena area,
- Buildings in the municipality of Bologna and Modena,
- Border of the municipalities Bologna and Modena,
- Pilot area in Modena

2.9.2 The case of Stuttgart

- Physiological equivalent temperature (PET) for different areas in Stuttgart,

2.9.3 The case of Warsaw

- Border of the municipality of Warsaw,
- IGSO measurement points,
- UHI index,
- Universal Thermal Climate Index for Warsaw and various health resorts,
- Global solar radiation on the ground level (Mazovian Lowland),
- Reflected solar radiation (Mazovian Lowland),
- Air temperature (Mazovian Lowland),
- Wind velocity (Mazovian Lowland),
- Subjective Temperature Index (STI) (Mazovian Lowland).

2.9.4 The case of Prague

- Various raster climate data.

2.9.5 The case of Budapest

- Various raster climate data.

2.10 Other data

2.10.1 UHI Project Partners

For each UHI Project partner there is a location marked on the map and important links provided

2.11 Summary

In accordance the aims of the authors, this Manual for UHI assessment helps in selecting measurement locations as well as in identifying sampling infrastructures to be developed in the single urban areas. First of all, it is very important to determine the purpose of the station clearly: (i) to monitor the greatest impact of the city; (ii) to collect data for a more representative or typical district; (iii) to characterize a particular site, where climate problems are perceived to be or where future development is planned. In choosing a location and site for urban stations, there are three scales of interest in urban area studies: macro, local, and micro on horizontal scales. Horizontal and vertical representativeness of the stations should be also specified. After that, the next essential step in selecting an urban station site is to evaluate the physical nature of the urban surroundings and urban terrain (structure, cover, fabric, metabolism).

It is also very important to measure not only UHI components and indicators, i.e. urban and rural temperatures. For a better understanding of UHI phenomena, the measurements of solar radiation, air humidity, wind speed, and precipitation can be very useful. A wide range of technical parameters (such as time resolution, accuracy, range, uncertainty, and calibration requirements) of these meteorological measurements must be also mentioned in the development of UHI observation techniques and evaluation processes.

For a given urban zone, the complexity of the urban environment sets special requirements for siting observation equipment to provide representative values that are little affected by nearby buildings or pollution sources. The interpretation of atmospheric conditions between measuring sites requires detailed information about surface characteristics and the use of urban scale numerical models.

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Chapter 3

Methodologies for UHI analysis

Urban Heat Island Phenomenon And Related Mitigation Measures In Central Europe

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Abstract A central strand of research work in the realm of urban physics aims at a better understanding of the variance in microclimatic conditions due to factors such as building agglomeration density, anthropogenic heat production, traffic intensity, presence and extent of green areas and bodies of water. The characteristics and evolution of the urban microclimate is not only relevant to people's experience of outdoor thermal conditions in the cities. Higher air temperatures also exacerbate discomfort caused by the overheating of indoor spaces and increases cooling energy expenditures. It can be argued that the solid understanding of the temporal and spatial variance of urban microclimate represents a prerequisite for the reliable assessment of the thermal performance of buildings (energy requirements, indoor thermal conditions). In this context, the present treatment entails a three-fold contribution. First, the existence and extent of the UHI phenomena are documented for a number of Central-European cities. Second, a comprehensive assessment of the effectiveness of UHI mitigation measures in these cities is described that is conducted using advanced numeric modelling instruments. Third, a systematic framework is proposed to identify a number of variables of the urban environment that are hypothesized to influence UHI and the urban microclimate variance. These variables pertain to both geometric (morphological) and semantic (material-related) urban features.

Keywords Urban Climate, Urban Heat Island, Mitigation Measures, Simulation, Evaluation

Introduction

The characteristics of the urban microclimate are of critical importance with regard to inhabitants' health and well-being (thermal comfort, heat stress, mortality rates) as well as energy and environmental issues (Akbari 2005, Harlan and Rudell 2011). In the last few years, the general awareness concerning the urban microclimate has been steadily rising. However, given the fact that world-wide an increasing number of people live in cities, further research and planning efforts are needed to better understand and address the effects of urban microclimate, its variance, and its development. Given the complexity of the urban fabric, it is widely recognized that heat storage in urban areas will be higher when compared to unbuilt areas (Grimmond and Oke 1999, Piringer et al. 2002). Generally speaking, the undesired thermal circumstances in the urban environment are caused in part by certain properties of the materials used for construction of buildings, pavements, and roads, the urban layout and structure including topography, morphology, density, and open space configuration, as well as processes and activities such as transportation and industry (Unger 2004, Grimmond 2007, Alexandri 2007, Kleerekoper et al. 2012, Shishegar 2013). These factors can affect, amongst other things, the way solar radiation is absorbed by urban surfaces and the way air masses flow through the urban fabric. Empirical observations in many cities around the world point to significantly higher urban temperatures than the surrounding rural environment. This circumstance is referred to as the urban heat island (UHI) phenomenon (see, for example, Voogt 2002, Arnfeld 2003, Blazejczyk 2006, Oke 1981, Gaffin et al. 2008). Together with climate change, this phenomenon can be crucial to the way we view urban areas as living environments.

Recently, a number of research efforts have been initiated to better understand the very specifics of the UHI phenomenon (see, for example, Arnfeld 2003, Blazejczyk 2006). Some of related foci of these efforts are to describe the characteristics and patterns of UHI (Voogt 2002, Hart and Sailor 2007). Empirical observations have shown that the UHI phenomenon shows different characteristics during different seasons (Gaffin et al. 2008) and that it is pronounced differently during the night and the day (Oke 1981). Furthermore, the intensity of urban heat islands is believed to rise proportionally to the size and population of the urban area (Oke 1972). More recently, Gaffin et al. (2008) performed a detailed spatial study of New York City's current UHI and concluded that summer and fall periods were generally the strongest UHI seasons, consistent with seasonal wind speed changes in the area. A simple quantitative indicator of urban heat island phenomenon is the UHI intensity. The UHI intensity is defined as the difference between urban and rural air temperature (Oke 1972).

Generally, heat island intensities are quantified in the range of 1 to 3 K, but under certain atmospheric and surface conditions can be as high as 12 K (Voogt 2002). Material properties of urban surfaces (Grimmond et al. 1991, Akbari et al. 2001) as well as evapotranspiration, and anthropogenic heat emission (Taha 1997) can result in higher urban temperatures. To address the implications of the UHI phenomenon, cities (both governmental bodies and affected stakeholders) must implement well-conceived, comprehensive, and collective actions with a high potential to positively influence urban climate and remedy the negative phenomena associated with the urban heat islands.

In this context, the present contribution reports on the results of data analyses and modelling efforts undertaken to investigate the extent of urban heat island phenomena and the potential of relevant mitigation measures in the Central European region (Mahdavi et al. 2013). Thereby, a large set of data was collected and analysed concerning the extent of the UHI effect in multiple cities in Central Europe. Furthermore, to develop and demonstrate approaches toward supporting the process of design and evaluation of UHI mitigation measures, the potential of numerical (simulation-based) urban microclimate analysis models were explored.

As numerical modelling poses certain challenges not only in view of time and computational resources but also model validation and calibration issues, the potential of alternative (or complementary) empirically-based modelling options were investigated. To develop such alternative models, certain features of the urban environment are hypothesized to influence UHI and the urban microclimate variance. The related variables, which pertain to both geometric (morphological) and semantic (material-related) urban features are captured within a systematic framework.

The statistical relationships between the values of such variables and the extent of microclimatic variance provide the basis for simple empirically-based models. These models can be directly used to predict the impact of mitigation measures or indirectly applied to gauge the performance of detailed numerical models of the urban microclimate.

3.1 *The Urban heat island in central Europe*

Metropolitan areas worldwide vary in their spatial configuration. This is typically manifested in the diversity of the respective microclimatic conditions. The present contribution focuses on documenting this diversity in terms of the frequency, magnitude, and time-dependent (diurnal and nocturnal) UHI intensity distribution (during a reference week) and the long-term development of urban and rural temperatures in seven Central-European cities, namely Budapest, Ljubljana, Modena, Padua, Prague, Stuttgart, Vienna, and Warsaw (see Tables 3.1 and 3.2). The magnitude of the UHI effect can be expressed in terms of Urban Heat Island intensity (UHI). This term denotes the temperature difference (in K) between simultaneously measured urban and rural temperatures. The aim was to identify and evaluate the extent of the UHI effect and its variance in the broader geographical context of the participating cities.

City	Area [km ²]	Population [millions]	Latitude	Longitude	Altitude [m]
Budapest	525	1.74	47° 30' N	19° 3' E	90-529
Ljubljana	275	0.28	46° 3' N	14° 30' E	261-794
Modena	183	0.18	44° 39' N	10° 55' E	34
Padua	93	0.21	45° 25' N	11° 52' E	8-21
Prague	496	1.26	50° 5' N	14° 25' E	177-399
Stuttgart	207	0.60	48° 46' N	9° 10' E	207-548
Vienna	415	1.73	48° 12' N	16° 22' E	151-543
Warsaw	517	1.70	52° 13' N	21° 00' E	76-122

Tab 3.1 General information about the participating cities

City	Topology
Vienna	Vienna is located in north-eastern Austria, at the eastern most extension of the Alps in the Vienna Basin.
Stuttgart	Stuttgart's center lies in a Keuper sink and is surrounded by hills. Stuttgart is spread across several hills, valleys, and parks.
Padua	Padua is located at Bacchiglione River, 40 km west of Venice and 29 km southeast of Vicenza. The Brenta River, which once ran through the city, still touches the northern districts. To the city's south west lie the Euganaean Hills.
Budapest	The Danube River divides Budapest into two parts. On the left bank the Buda is located, with over 20 hills within the territory of the capital, and on the right bank the flat area of Pest is located with its massive housing, as well as commercial and industrial areas.
Prague	Prague is situated on the Vltava river in the center of the Bohemian Basin.
Modena	Modena is bounded by the two rivers Secchia and Panaro, both affluent of the Po River. The Apennines ranges begin some 10 km from the city, to the south.
Warsaw	Warsaw is located some 260 km from the Baltic Sea and 300 km from the Carpathian Mountains. Furthermore, Warsaw is located in the heartland of the Masovian Plain.
Ljubljana	Ljubljana is located in the Ljubljana Basin between the Alps and the Karst Plateau.

Tab. 3.2 Information about the urban topology of the participating cities

As already mentioned, UHI intensity in observed urban areas was derived for a reference summer week (with high air temperature and relatively low wind velocity) selected by each participating city independently. The collected information included hourly data on air temperature, wind speed, and precipitation from two representative weather stations (one urban and one rural).

To obtain a long-term impression of the urban and rural temperature development, mean annual (urban and rural) temperatures and UHI values were derived for a period of up to 30 years, namely from 1980 to 2011 (Modena, Prague, Stuttgart, Warsaw), from 1994 to 2011 (Vienna, Padua), from 2000 to 2011 (Budapest).

Table 3.3 provides an overview of the time periods used for both the short-term and the long-term analyses.

	Reference Week	Long-term Climate Data	
		URBAN STATION	RURAL STATION
Budapest	20-26.8.2011	2000-2011	2000-2011
Ljubljana	20-26.8.2011	1980-2011	1980-2011
Modena	20-26.8.2011	1980-2010	1980-2009
Padua	18-24.8.2011	1994-2011	1994-2011
Prague	8-14.7.2010	1980-2011	1980-2011
Stuttgart	20-26.8.2011	1981-2011	1980-2011
Vienna	20-26.7.2011	1994-2011	1994-2011
Warsaw	9-15.6.2008	1980-2011	1980-2011

Tab. 3.3 Overview for the data sets used for the analysis

3.2 Short-term analyses of the observations

Fig. 3.1 shows the cumulative frequency distribution of UHI values for the participating cities for the aforementioned summer reference week. Fig. 3.2 and 3.3 show for a reference summer day (representing the reference week) the hourly values of urban temperature and the hourly UHI values respectively.

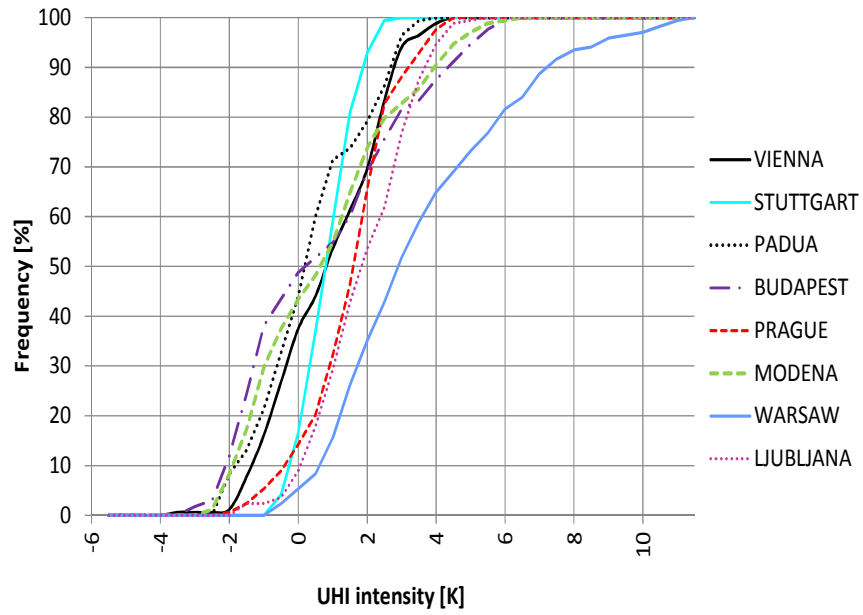


Fig. 3.1 Cumulative frequency distribution of UHI intensity for a one week summer period

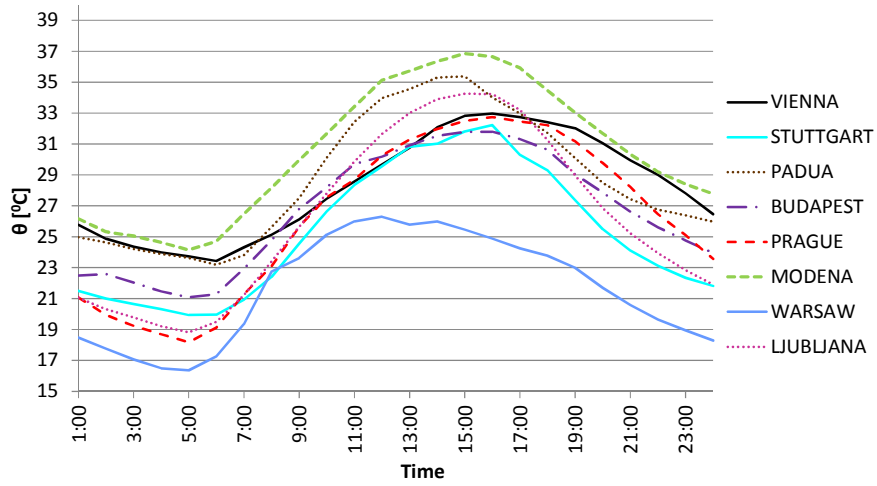


Fig. 3.2 Mean hourly urban temperature for a reference summer day

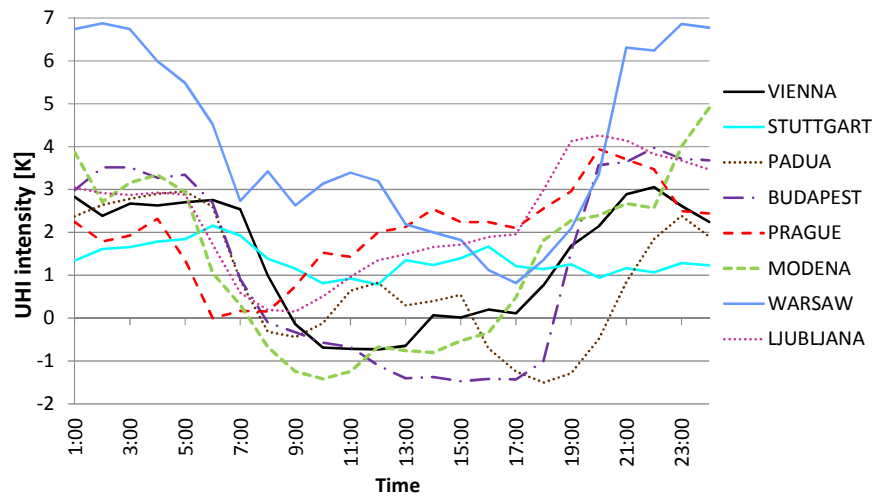


Fig. 3.3 Mean hourly UHI intensity distribution for a reference summer day

The reference week data clearly demonstrate the existence and significant magnitude of the UHI effect in participating cities, especially during the night hours (Fig. 3.3). However, the time-dependent UHI patterns vary considerably across the participating cities. In Warsaw, for example, UHI intensity level ranges from around 1 K during daytime to almost 7 K during the night, while in Stuttgart levels are rather steady, ranging from 1 K to 2 K. The UHI pattern differences are also visible in the cumulative frequency distribution curves of Fig. 3.1. In this Figure, a shift to the right denotes a larger UHI magnitude.

3.3 Long-term analyses of the observations

Fig. 3.4 and 3.5 show the (mean annual) urban and rural temperatures respectively over a period of 30 years. Figures 3.6 and 3.7 show the long-term UHI intensity trend over the same period. The historical temperature records suggest an upward trend concerning both urban and rural temperatures (see Figures 3.4 and 3.5). Consistent with regional and global temperature trends, a steady increase in rural temperatures of up to about 2.5 K can be observed in all selected cities with the exception of Budapest. This might be due to the small sample of data set obtained, as this particular weather station was installed in the year of 2000. In the same 30-years period, the mean annual urban temperature rose somewhere between 1 K (Stuttgart) and 3 K (Warsaw). A number of factors may have contributed to this trend, namely increase in population, energy use, anthropogenic heat production, and physical changes in the urban environment (e.g., more high-rise buildings, increase in impervious surfaces). It should be noted that, while both rural and urban temperatures have been increasing, the value of the UHI intensity has been rather steady. Our data suggest increasing UHI intensity trends in Warsaw and Ljubljana, whereas a slight decrease can be discerned from Stuttgart and Prague data (Fig. 3.6 and Fig. 3.7).

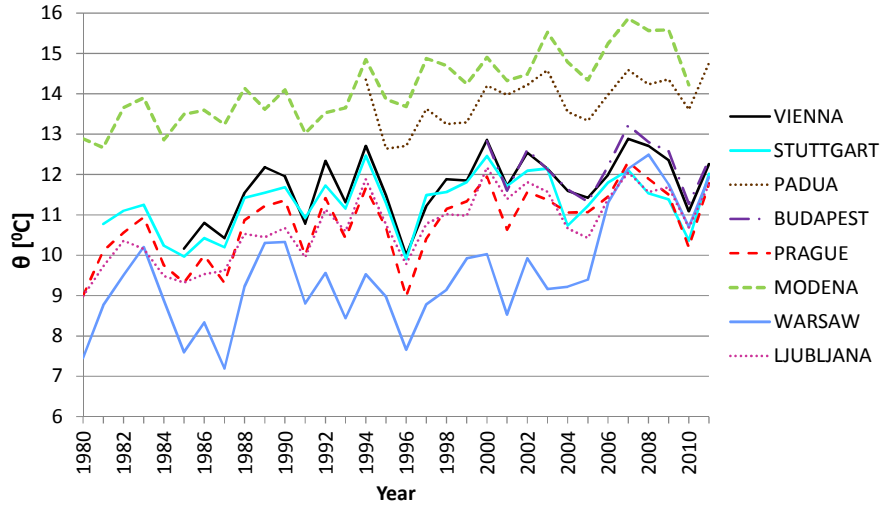


Fig. 3.4 Development of (mean annual) urban temperatures over a period of 30 years

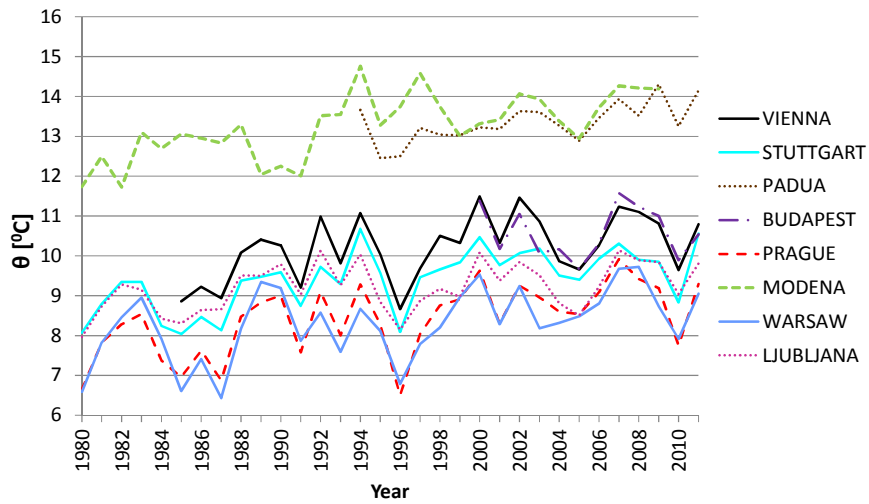


Fig. 3.5 Development of (mean annual) rural temperatures over a period of 30 years

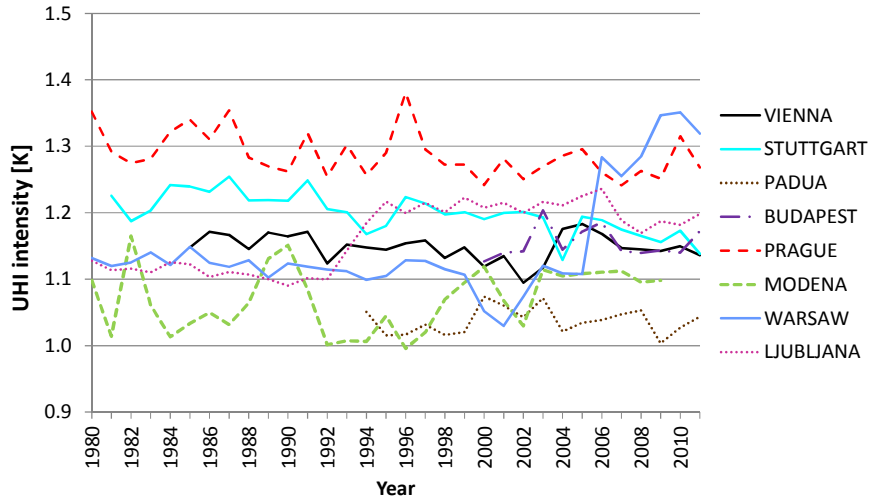


Fig. 3.6 Long-term development of the UHI intensity over a period of 30 years

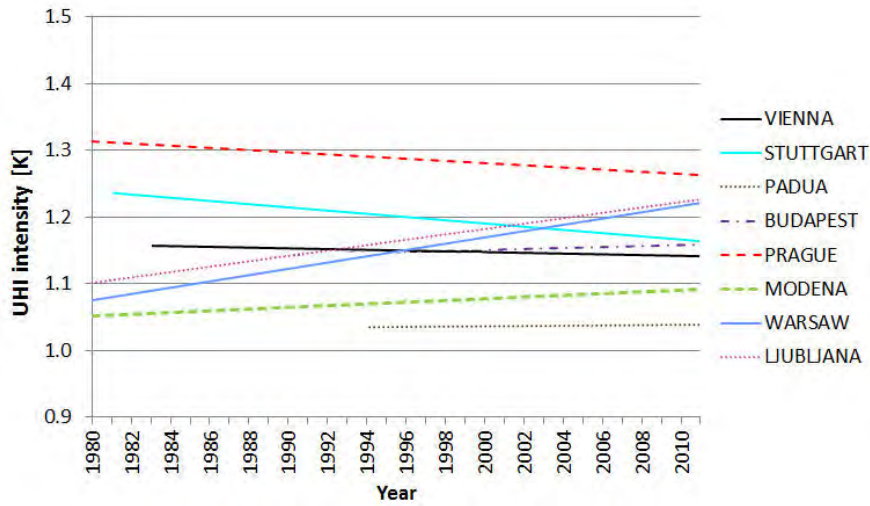


Fig. 3.7 Long-term UHI intensity trend over a period of 30 years

3.4 Modelling efforts

Urban microclimate is considered to be a cumulative effect of several circumstances, including small-scale processes such as combustion process of vehicles and meso-scale interactions such as atmospheric forces. To properly model and analyse these effects, computational tools must consider them concurrently and in an integrated fashion. Hence detailed and complex simulation approaches are needed that have the potential to incorporate multiple aspects including hygro-thermal processes and related human comfort issues. The resulting improved predictive performance of proper computational tools would thus provide valuable feedback to planners and decision makers in confronting the UHI phenomenon.

An increasing number of tools are becoming available for microclimatic modelling of urban areas (Mirzaei and Haghighat 2010). Some tools are rather limited in terms of the range of pertinent variables they consider. Other, more detailed tools display limitations in terms of domain size and resolution. Nonetheless, numerical models still present a valuable resource for the assessment of complex thermal processes in the urban field. Within the context of this contribution, we focus on a state of art CFD-based numeric simulation environment ENVI-met (Huttner and Bruse 2009). This tool was selected as it has the capability to simulate the urban micro-climate while considering a relatively comprehensive range of factors (building shapes, vegetation, different surface properties). The high-resolution output generated by this tool includes air, soil, and surface temperature, air and soil humidity, wind speed and direction, short wave and long wave radiation fluxes, and other important microclimatic information.

Project partners undertook an extensive modelling effort including the following steps. First, a specific area within each city was selected. The idea was to select areas that are either targeted for the implementation of mitigation measures or represent likely candidates for such measures (“pilot action areas”). Second, these areas were specified in detail with regard to required model input information (i.e., geometric and semantic properties). Third, the existing microclimatic circumstances for these areas (base case) were modelled using the aforementioned simulation environment. Fourth, candidate mitigation measures were defined for each of these areas (see Tab. 3.4 for an overview). Fifth, the envisioned mitigation measures were virtually implemented in the simulation environment and corresponding output was generated. Sixth, the base case conditions were compared with the predicted post-mitigation circumstances to provide a quantitative basis for the evaluation of the effectiveness of the envisioned mitigation measures.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Budapest	Green area + Water bodies	Trees	-	-	-
Ljubljana	Green area	Water bodies	-	-	-
Modena	Green area	Cool walls	Green roofs	Pervious ground	Cool roofs
Padua	Green area + Trees	Cool pavements	Cool roofs	S1 + Cool pavements	-
Prague	New urban development	Green roofs	-	-	-
Stuttgart	Green area	Trees	Water bod- ies	-	-
Vienna	Trees	Green roofs	Combined	-	-
Warsaw	Green area + Trees + Green roofs	S1 + Pervious pavements	-	-	-

Tab. 3.4 Summary of envisioned mitigation measures

To illustrate the kinds of information and analyses that can be obtained from the modelling process, relevant results are provided below for three cities, namely Vienna, Padua, and Warsaw. Toward this end, Figures 3.8 to 3.10 show the mean hourly temperature in the course of a reference summer day in Vienna, Padua, and Warsaw for the base case and three mitigation scenarios. Figures 3.11 to 3.13 show the corresponding temperature differences between the base case and the applicable mitigation scenarios in the course of a reference summer day. These results point to the potential of various mitigation measures to reduce air temperature levels in hot summer days in the selected cities. As it could be expected, different mitigation measures display different levels of impact. For example, in case of the targeted area in Vienna, green roofs do not appear to noticeably influence

the air temperature in the urban canyon. Trees, on the other hand, do impact the air temperature. The combination of these two measures proved in this case to be most effective. With regard to the temporal pattern of the effects, it can be noted that the difference in air temperature is more pronounced during evening and night hours.

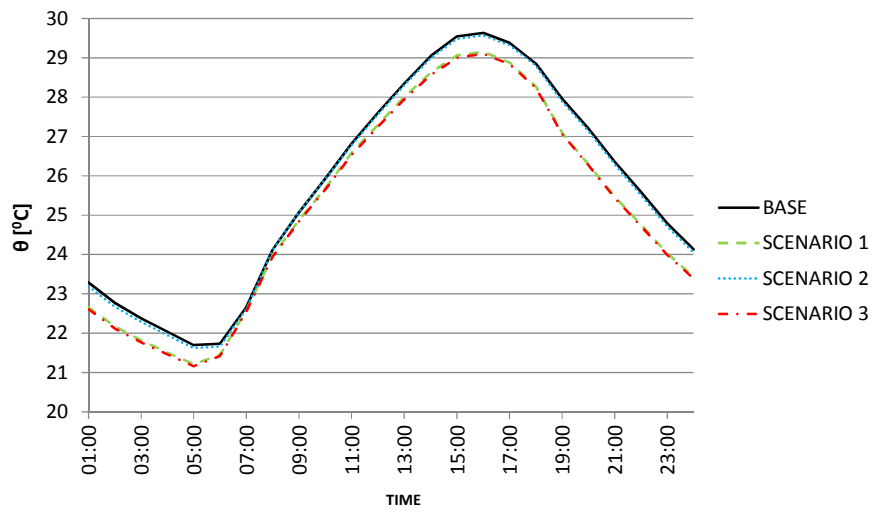


Fig. 3.8 Mean hourly temperature in the course of a reference summer day in Vienna for the base case and three mitigation scenarios

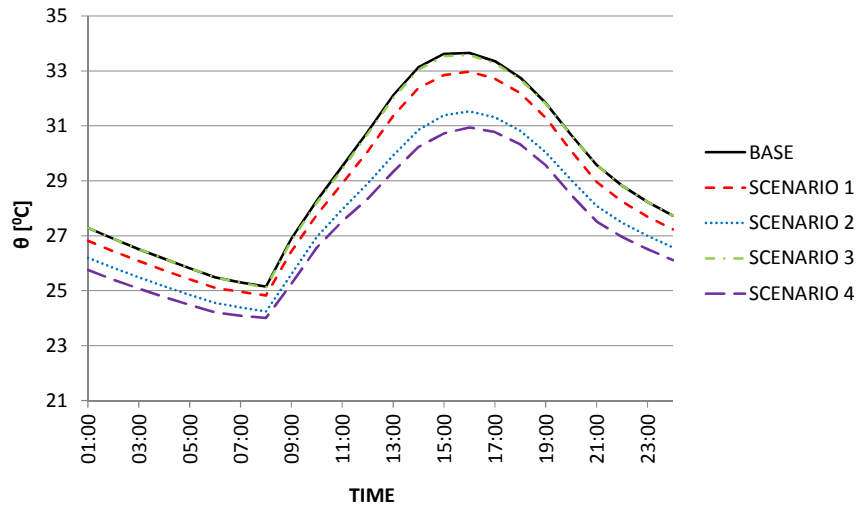


Fig. 3.9 Mean hourly temperature in the course of a reference summer day in Padua for the base case and four mitigation scenarios

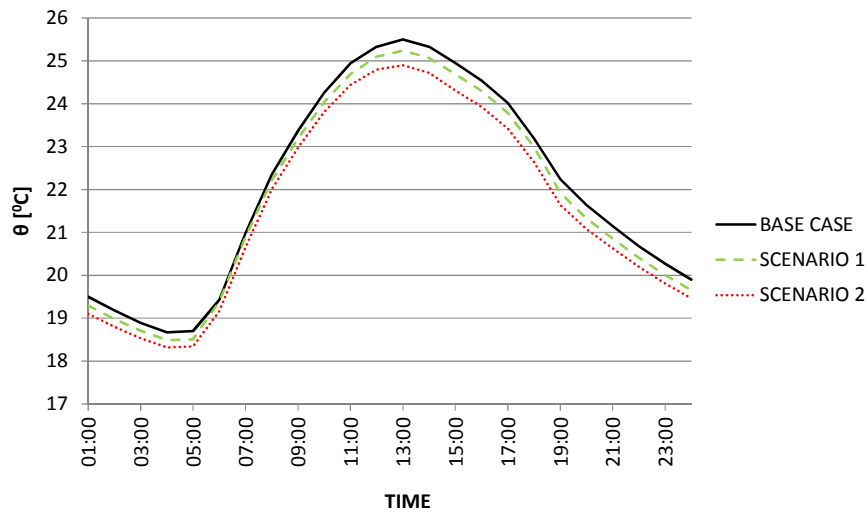


Fig. 3.10 Mean hourly temperature in the course of a reference summer day in Warsaw for the base case and two mitigation scenarios

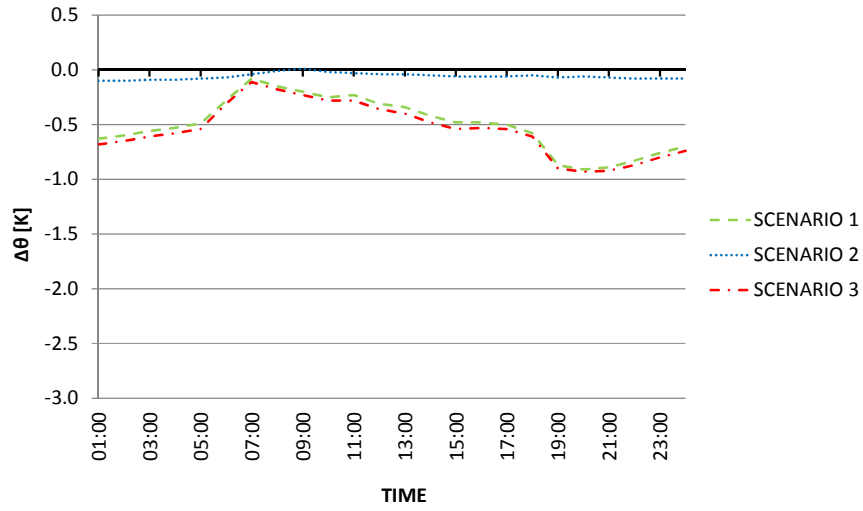


Fig. 3.11 Temperature difference between the base case and three mitigation scenarios in the course of a reference summer day in Vienna

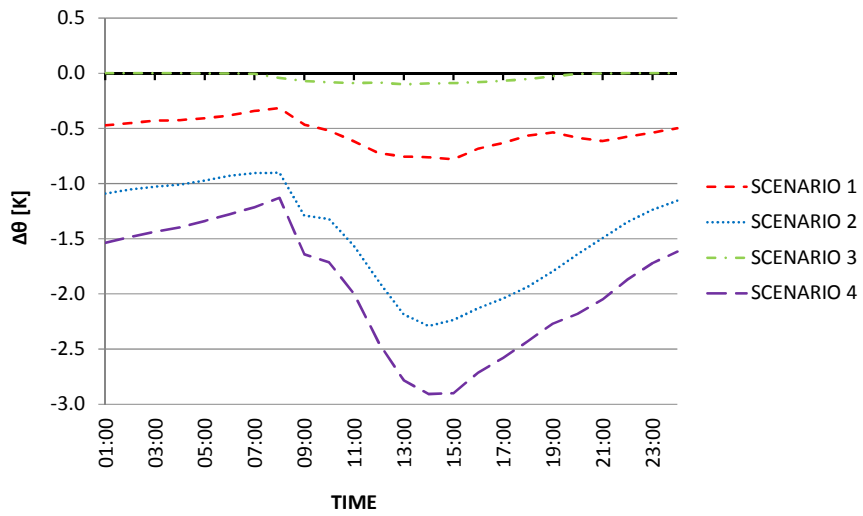


Fig. 3.12 Temperature difference between the base case and four mitigation scenarios in the course of a reference summer day in Padua

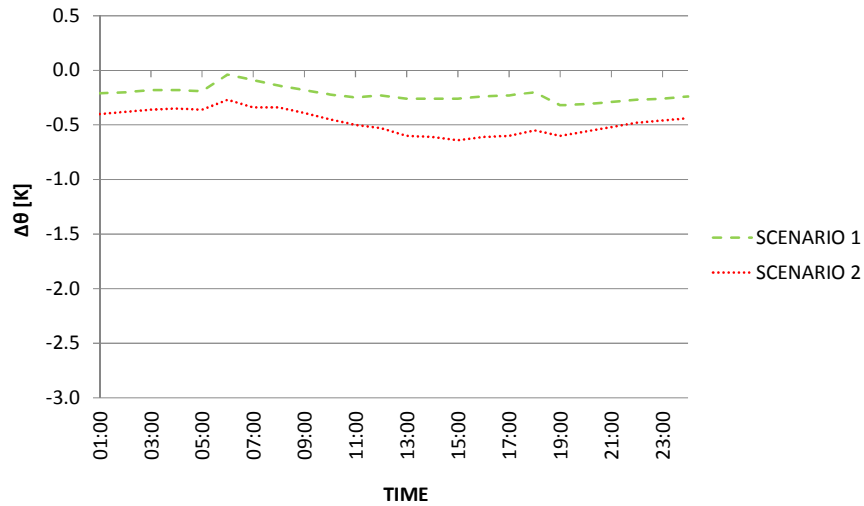


Fig. 3.13 Temperature difference between the base case and two mitigation scenarios in the course of a reference summer day in Warsaw

To further investigate the temporal nature of UHI intensity values (and their sensitivity to various mitigation measures, we introduced the concepts of Cumulative Temperature Increase (CTI) and Cumulative Temperature Decrease (CTD). CTI and CTD are computed as the cumulative sum of all positive and negative values respectively in the course of a reference day:

$$CTI = \sum_{i=1}^{24} (\theta_{B,i} - \theta_{S,i}) \quad \text{for all intervals when } B_i < S_i$$

Eq. 1

$$CTD = \sum_{i=1}^{24} (\theta_{B,i} - \theta_{S,i}) \quad \text{for all intervals when } B_i > S_i$$

Eq. 2

A summary of the results (predicted CTD and CTI values for summer and winter seasons for all mitigation measures in all cities) is provided in Tab. 3.5.

City	Mitigation measures	Summer		Winter		
		CTD	CTI	CTD	CTI	
Vienna	S1	Trees	12	0	1	0
	S2	Green roofs	1	0	0	0
	S3	Combined	13	0	1	0
Stuttgart	S1	Green area	7	0	99	0
	S2	Trees	7	0	0	6
	S3	Water bodies	0	0	11	0
Padua	S1	Green area + trees	13	0	1	0
	S2	Cool pavements	35	0	6	0
	S3	Cool roofs	1	0	0	2
	S4	S1 + cool pavements	47	0	6	0
Budapest	S1	Green area + water bodies	16	7	18	0
	S2	Cool walls	0	4	0	1
Modena	S3	Green roofs	6	0	1	0
	S5	Cool roofs	2	0	1	0
Warsaw	S1	Green area + trees + green roofs	5	0	0	0
	S2	S1 + pervious pavements	11	0	1	0

City	Mitigation measures	Summer	Winter	City	Mitigation measures	Summer
Ljubljana	S1	Trees + green roofs + green area	1	0	2	0
	S2	S1 + pervious pavements	0	0	0	0

Tab. 3.5 Summary of predicted CTD and CTI values for summer and winter seasons for all mitigation measures in all cities

These results illustrate the potentially significant utility of the modelling tools and approaches for decision making processes pertaining to the proper choice of UHI mitigation measures. However, as with other areas of applied numerical modelling, certain important challenges must be addressed. One issue is related to the rather extensive time and computational resources that are necessary for proper deployment of complex simulation tools. A second challenge pertains to the issue of model reliability: Even highly detailed and mathematically consistent simulation tools may yield erroneous results given incomplete (or inaccurate) input data.

The high level of domain complexity involved in urban microclimate modelling aggravates this model reliability problem. To exemplify this circumstance, consider the simple case of predicting the air temperature in a specific location in the city of Vienna. In this case, the actual air temperature measurements at this location were compared with simulated results, whereby different tool versions and settings as well as different forcing parameter were considered. The results (see Fig. 3.14) suggest that predictions based on computation may significantly deviate from actual measurements, thus undermining the practical usability of modelling tools. An important approach to address the model reliability issue focuses on model calibration potential (Maleki et al. 2014).

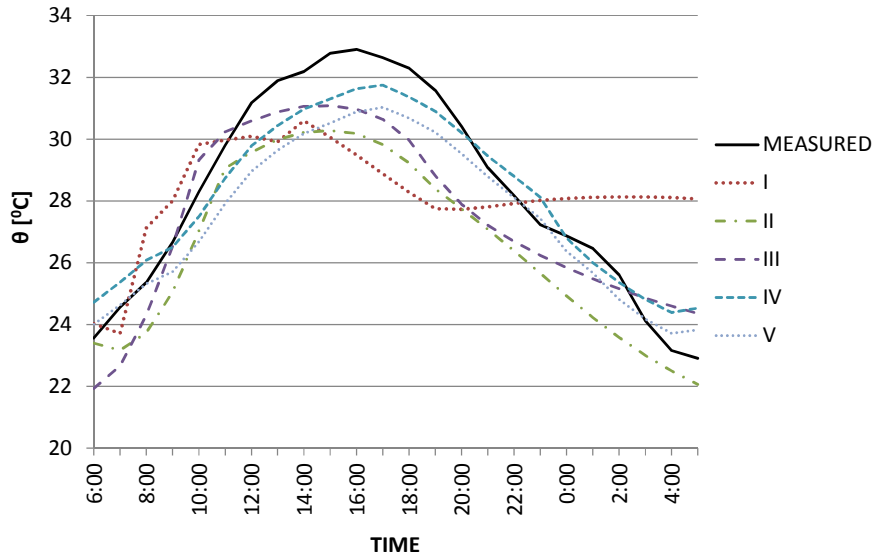


Fig. 3.14 Comparison of the measured mean hourly temperature in the course of a summer day (22nd July 2010) in Vienna with simulation results conducted with various simulation setting and forcing parameter options (cases I to V)

In addition to numerical modelling, we explored the potential of simple empirically-based relationships between fundamental features of the urban setting (morphology, materials) and basic microclimatic variables. Such relationships would not only provide efficient means for rough estimations of the effectiveness of mitigation measures, but would also provide a basic plausibility check for the results of numerical computation. Hence, within the framework of the project, we developed a systematic framework toward definition and derivation of fundamental variables of a selected urban area. These variables are hypothesized to influence UHI and the urban microclimate variance. They pertain to both geometric (morphological) and semantic (material-related) urban features are captured within a formal and systematic framework.

3.5 A Systematic framework for the representation of urban variables

Within the UHI project, a systematic framework was developed (Mahdavi et al. 2013) to assess – for a specific urban location, hereafter referred to as urban unit of observation (U2O) – the urban heat island phenomenon, to specify potential mitigation measures, and to evaluate such measures via adequate empirically-based calculation methods. The framework involves the following steps:

- i) Definition of "Urban Units of Observation" (U2O): These are properly bounded areas within an urban setting selected as the target and beneficiary of candidate UHI mitigation measures;
- ii) Description of the status quo of U2O in terms of a structured set of geometric and physical properties;
- iii) Specification of the existing extent of UHI in terms of proper indicators;
- iv) Specification of the candidate mitigation measures in terms of projected changes to the geometric and/or physical properties captured in step ii above;
- v) Prediction of the effect of mitigation measures using empirically-based calculation methods;
- vi) Expression of the mitigation measures' impact in term of predicted changes in the extent of UHI.

In this framework, the notion of U2O is applied to systematically address the local variation of the urban climate throughout a city. A spatial dimension (diameter) of approximately 400 to 1000 m has been targeted for U2O.

As the urban microclimate is believed to be influenced by different urban morphologies, structures, and material properties, a set of related variables were identified and included in our framework (Tab. 3.5.6 and 3.5.7) based on past research (Nowak 2002, Piringer et al. 2002, Burian et al. 2005, Ali-Toudert and Mayer 2006) and our own investigations (Mahdavi et al. 2013, Kiesel et al. 2013).

The geometric properties are meant to capture the urban morphology of an U2O. The physical properties describe mainly the thermal characteristics of urban surfaces. These properties are often considered as fundamental factors in view of the heat balance of urban systems (Rosenfeld et al. 1995).

Geometric properties	Definition
Sky View Factor	Fraction of sky hemisphere visible from ground level
Aspect ratio	Mean height-to-width ratio of street canyons
Built area fraction	The ratio of building plan area to total ground area
Unbuilt area fraction	The ratio of unbuilt plan area to total ground area
Impervious surface fraction	The ratio of unbuilt impervious plan area to total ground area
Pervious surface fraction	The ratio of unbuilt pervious surface area to total ground area
Mean building compactness	The ratio of built volume (above terrain) to total building plan area
Built surface fraction	The ratio of total built surface area to total built area
Wall surface fraction	The total area of vertical surfaces (walls)
Roof surface fraction	The total area of horizontal surfaces (roofs)
Mean sea level	Average height above sea level

Tab. 3.6 Variables to capture the geometric properties of an U2O

Surface/material properties	Definition
Reflectance/albedo	Fraction of reflected direct and diffuse shortwave radiation
Emissivity	Ability of a surface to emit energy by radiation (longwave)
Thermal conductivity	Property of a material's ability to conduct heat, given separately for impervious and pervious materials
Specific heat capacity	Amount of heat required to change a body's temperature by a given amount, given separately for impervious and pervious materials
Density	Mass contained per unit volume, given separately for impervious and pervious materials
Anthropogenic heat output	Heat flux density from fuel combustion and human activity (traffic, industry, heating and cooling of buildings, etc.)

Tab. 3.7 Variables to capture the surface and material properties of an U2O

To derive the specific values of the U2O variables for the selected urban areas, we used data provided by the city of Vienna in a form of a Digital Elevation Model (DEM). The DEM consisted of a terrain and a surface model, including building footprints in form of closed polygons associated with building height data (which indicates the height of the building eaves). QGIS (Quantum GIS 2013), an open source Geographic Information System, was used to visualize, manage, and analyse the data. A specific set of algorithms was developed (Glawischnig et al. 2014) and further used for the quantitative analysis of the microclimatic attributes.

To exemplify and illustrate the application of the aforementioned algorithms and procedures, Fig. 3.15 depicts computed values of a selected set of geometric and semantic variables for four locations across Vienna. The selected locations include both low-density suburban and high-density urban typologies in Vienna (Tab. 3.8). Given the specific arrangement of the respective scales in this representation (descending versus ascending order of the scale numbers), it can support the recognition of distinct differences between the selected locations.

A clear shift to the left in Fig. 3.15 denotes a more suburban character, while the shift to the right denotes a more urban character.

	NAME	TYPE	ELEVATION
A	Innere Stadt	Urban (city center)	177 m
B	Gaudenzdorf	Urban	179 m
C	Hohe Warte	Urban (peripheral)	198 m
D	Donaufeld	Suburban	161 m

Tab. 3.8 Information regarding the selected locations in the city of Vienna

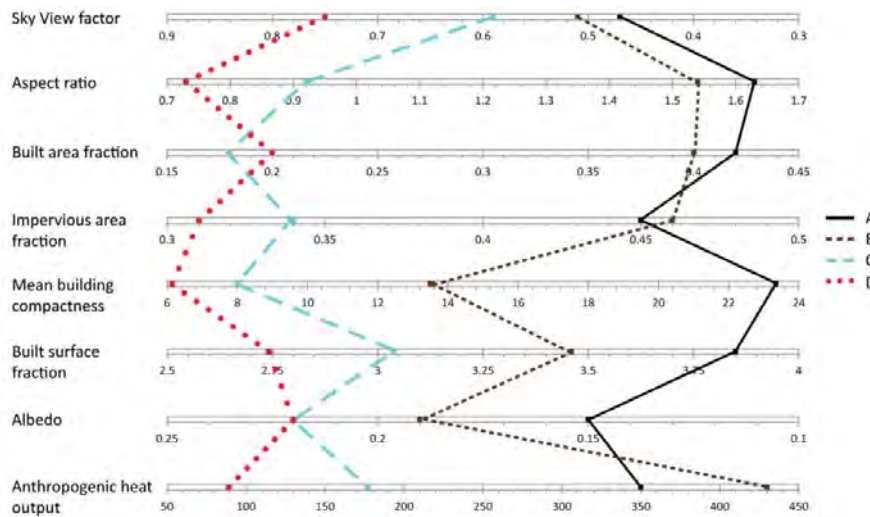


Fig. 3.15 The computed values of a number of U2O variables for the urban areas around the aforementioned five weather station locations

Once U2Os and their respective variables are derived, the existence and extent of the correlations between urban microclimate variance and the U2O variables are explored. These statistically significant correlations could provide a useful basis toward developing empirically-based predictive models. Such models

could support, amongst other things, decision making processes with regard to the selection of appropriate mitigation measures that are intended to address the UHI phenomena.

Ongoing work in this area involves the collection of information on urban microclimate variance and the analysis of its hypothesised relationship to U2O variables. While certain U2O variables (impervious surface fraction, anthropogenic heat emission) are hypothesised to positively correlate with indicators of UHI phenomenon, others (sky view factor, albedo) are more likely to display a negative correlation. While the state of progress in this area has not reached the point to warrant solid and generally valid relationships, initial findings appear to be promising. For example, Fig. 3.16 illustrates the relationship between urban surface albedo (determined for four location across Vienna) and the measured summer-time CTI in those areas.

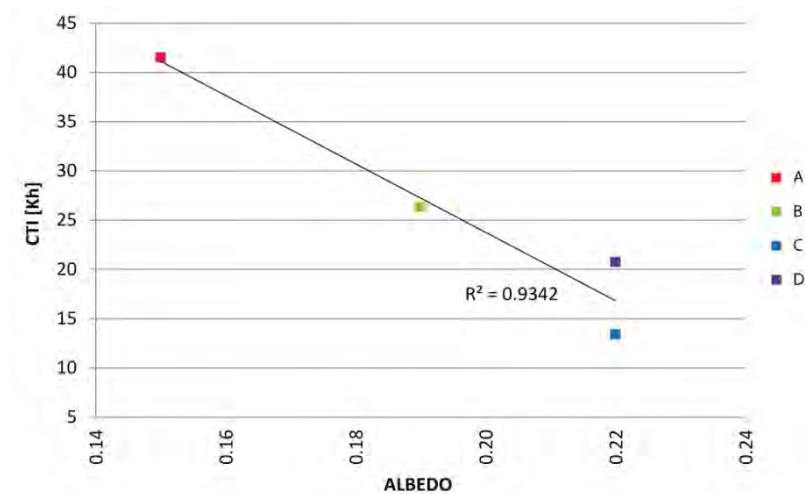


Fig. 3.16 Correlation between the albedo and CTI values for summer period for selected areas (A to D) in Vienna

3.6 Conclusion

We presented the results of EU-supported project concerned with the extent of the UHI phenomena in a number of Central European cities. The objectives of this project are to provide a common understanding of the UHI effects and to conceive and evaluate appropriate mitigation and adaptation measures. Short-term and long-term data with regard to urban and rural temperatures demonstrate the existence and significant magnitude of the UHI effect in a number of Central European cities. Furthermore observations based on hourly data display distinguished patterns implying larger UHI intensities during the night hours. To address the need for effective means of evaluating and mitigating UHI effects a comprehensive modelling effort was undertaken. Thereby, the ramifications of potential mitigation measures in selected areas of the participating cities were investigated using advance numeric modelling tools and techniques. Moreover, a systematic framework was developed and tested, which proposed and tested a number of geometric (morphological) and semantic (material-related) variables of the urban environment. These variables are hypothesized to influence UHI and the urban microclimate variance. Currently, the suggest link is being explored and statistically analysed. This work is expected to not only provide empirical data for the validation of numeric models, but also to support the formulation of simplified approaches toward estimation of mitigation measures effectiveness in view of UHI phenomena.

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3.7 Relevance of thermal indices for the assessment of the Urban Heat Island

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Abstract Urban areas, with their specific characteristics, modify the atmosphere and produce their own meso- and micro climate. The major aspect of this chapter is the discussion of methods for the quantification and assessment of the urban micro-climate and the most known and world-wide studied phenomenon, the Urban Heat Island (UHI). Four urban measurement stations and one rural measurement station are used to quantify the temporal and spatial climatic characteristics in Stuttgart, Germany. For the quantification of the urban micro-climate and the UHI human thermal, comfort indices were applied. These indices, namely Physiologically Equivalent Temperature and the Universal Thermal Climate Index, are used to describe the integral effect of urban thermal atmosphere, based on the energy exchange of the human body. These indices, following the concept of equivalent temperature, are applied to quantify the integral effect of air temperature, air humidity, wind and radiation fluxes, expressed as mean radiant temperature.

Introduction

Urban areas, with their artificial materials and specific morphology, act as an obstacle to the atmosphere, altering energy-balance, the chemical composition as well as the wind field (Landsberg 1981, Oke 1982, Oke & Cleugh 1987, Helbig et al. 1999). The urban heat island (UHI), describing the urban-rural surface and air temperature differences, is the most prominent and world-wide studied phenomenon of urban climate (e.g. Böhm & Gabl 1978, Katsoulis & Theoharatos 1985, Kuttler et al. 1996, Runnalls & Oke 2000, Johansson & Emmanuel 2006).

In fact, the intensity of the urban heat island depends on e.g. land-use, building ratio, population density and vegetation (e.g. Landsberg 1981, Oke 1981,

1982). Before establishing mitigation and adaptation measures counteracting the urban heat island, city planners and officials need to comprehend the spatial and temporal dimensions of the meteorological and climatological conditions in a city (Matzarakis et al. 2008, Ketterer & Matzarakis 2014). As city dwellers are the main target of city planners, the integral effect of air temperature, air humidity, wind speed and radiation fluxes on humans in a city has to be quantified and assessed (Eliasson 2000, Ketterer & Matzarakis 2014). Hence, modern human-biometeorological methods for quantification of the spatial and temporal distribution of the UHI as well as to assess mitigation and adaptation measures for improving outdoor meteorological conditions have to be applied (Kuttler 2011, 2012, Matzarakis 2013).

Urban planners require information about the human biometeorological conditions in terms of frequencies (e.g. number of days or hours per year or season), as well as the quantification of temperature differences between different planning scenarios. The quantification of heat stress and its reduction by planning measures is a big challenge, especially in the light of climate change (Matzarakis & Endler 2010, Thorsson et al. 2011). Due to climate change, the mean air temperature is expected to increase and also heat waves are assumed to become more frequent, more intense and longer lasting (Meehl & Tebaldi 2004, Schär et al. 2004). Thus, there is a demand for the assessment and quantification of adaptation measures improving the urban climate, i.e. street morphology, different types of vegetation. This approach is twofold: the analysis and description of single places for urban planning measures and the construction of maps for the detection of areas with frequent heat stress (Svensson et al. 2003).

The aim is to show and describe methods based on long term measured data and their analysis for a comprehensive quantification of urban-rural differences and possible strategies for adaptation and mitigation in urban areas, focused on micro scale conditions.

3.7.1 Methods and data

The application of thermal indices based on the human energy balance gives detailed information on the effect of complex thermal environments on humans (Höppe 1999). It is related to the close relationship between the human thermoregulatory mechanism and the human circulatory system. The human body does not have any selective sensors for the perception of individual climatic parameters.

Thermoreceptors can register the temperature of the skin and blood flow passing the hypothalamus and response thermoregulatorily (Höppe 1993, Höppe 1999). These temperatures, however, are influenced by the integrated effect of all climatic parameters, which are in some kind of interrelation, i.e. affect each other (VDI 1998, Höppe 1999).

Commonly used thermal indices, based on the human energy balance, are Predicted Mean Vote PMV (Fanger 1972), Physiologically Equivalent Temperature PET (Mayer & Höppe 1987, Höppe 1999, Matzarakis et al. 1999), Standard Effective Temperature SET* (Gagge et al. 1986) or Outdoor Standard Effective Temperature Out_SET* (Spagnolo & Dear 2003), Perceived Temperature pT (Staiger et al. 2012) and Universal Thermal Climate Index UTCI (Jendritzky et al. 2012). These thermal indices require the same meteorological input parameters: air temperature, air humidity, wind speed, short and long wave radiation fluxes. These input parameters have a temporal and spatial variability, which have a huge influence on thermal indices. Wind speed and mean radiant temperature have the highest variability and are modified by surroundings and obstacles in complex urban areas. Thus, it is particularly important to calculate correctly these parameters and to perform the measurements with high quality and exactness (i.e. including artificial ventilation and radiation shield for air temperature measurements).

The basis for these thermal indices is the energy balance equation for the human body:

$$M+W+R+C+ED+ERe+ESw+S=0 \quad (1)$$

where, M represents the metabolic rate (internal energy production), W the physical work output, R the net-radiation of the body, C the convective heat flow, ED the latent heat flow to evaporate water diffusing through the skin (imperceptible perspiration), ERe the sum of heat flows for heating and humidifying the inspired

air, E_{Sw} the heat flow due to evaporation of sweat, and S the storage heat flow for heating or cooling the body mass.

The individual terms in this equation have positive signs if they result in an energy gain for the body and negative signs in the case of an energy loss (M is always positive, W, ED and E_{sw} are always negative). The unit of all heat flows is in Watt (Höppe 1999).

The individual heat flows in Eq. 1, are controlled by the following meteorological parameters (VDI 1998, Höppe 1999):

- air temperature: C, E_{Re}
- air humidity: ED, E_{Re}, E_{Sw}
- wind velocity: C, E_{Sw}
- radiant temperature: R

The thermo-physiological parameters heat resistance of clothing (clo) and activity of humans (in W) are required in addition (Fig. 3.7.1).

From the energy balance, which is primarily designed for the calculation of a thermal index like PET, are the indices which enable the user to predict “real values” of thermal quantities of the body, i.e. skin temperature, core temperature, sweat rate or skin wetness.

For this purpose, it is necessary to take into account all basic thermoregulatory processes, like the constriction or dilation of peripheral blood vessels and the physiological sweat rate (Höppe 1993, 1999).

An example of thermophysiological heat-balance model is the Munich Energy Balance Model for Individuals (MEMI) (Höppe 1993), which is the basis for the calculation of the Physiologically Equivalent Temperature, PET.

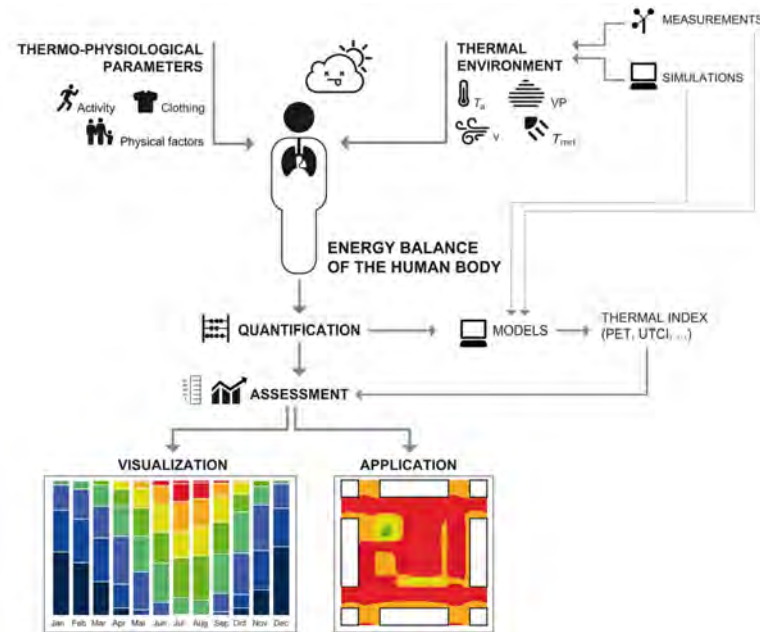


Fig. 3.7.1.1 Flowchart of the human-biometeorological assessment of the thermal environment.

Physiologically Equivalent Temperature

The Physiologically Equivalent Temperature (PET) is the equivalent temperature at a given place (outdoors or indoors) to the air temperature in a typical indoor setting with core and skin temperatures equal to those under the conditions being assessed. Thereby, the heat balance of the human body with a work metabolism 80 W (light activity, added to basic metabolism) and a heat resistance of clothing 0.9 clo) is maintained (Höppe 1999).

The following assumptions are made for the indoor reference climate:

- mean radiant temperature equals air temperature ($T_{mrt}=T_a$).
- air velocity (wind speed) is fixed at $v = 0.1$ m/s.
- water vapor pressure is set to 12 hPa (approximately, equivalent to a relative humidity of 50% at $T_a = 20^\circ\text{C}$).

The procedure for the calculation of PET contains the following steps:

1. calculation of the thermal conditions of the body with MEMI for a given combination of meteorological parameters.
2. insertion of the calculated values for mean skin temperature and core temperature into the model MEMI and computation the energy balance equation system for the air temperature T_a (with $v = 0.1$ m/s, $VP = 12$ hPa and $T_{mrt} = T_a$).
3. the resulting air temperature is equivalent to PET.

PET offers the advantage of a widely known unit (degrees Celsius), which makes results more comprehensible to regional or urban planners, who are not necessarily very familiar with the modern human-biometeorological methods (Matzarakis et al. 1999). The assessment classes of PET (Tab. 3.7.1) are valid only for the assumed values of internal heat production (80 W) and thermal resistance of the clothing (0.9)(Matzarakis & Mayer 1997).

The meteorological input parameters have to be measured or transferred to the average height of a standing person’s gravity center, 1.1m above ground (Matzarakis et al. 2009). These meteorological parameters can be measured or calculated by numerical models.

PET	Thermal Perception	Grade of Physiological Stress
	very cold	extreme cold stress
4 °C	-----	-----
	cold	strong cold stress
8 °C	-----	-----
	cool	moderate cold stress
13 °C	-----	-----
	slightly cool	slight cold stress
18 °C	-----	-----
	Comfortable	no thermal stress
23 °C	-----	-----
	slightly warm	slight heat stress
29 °C	-----	-----
	warm	moderate heat stress
35 °C	-----	-----
	hot	strong heat stress
41 °C	-----	-----
	very hot	extreme heat stress

Tab. 3.7.1.1 Ranges of the physiological equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings, internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo (according to Matzarakis & Mayer 1997)

Universal Thermal Climate Index

The Universal Thermal Climate Index UTCI (Jendritzky et al., 2012) is defined as the air temperature (T_a) of the reference condition causing the same model response as the actual condition. Thus, UTCI represents the air temperature, which would produce, under reference conditions, the same thermal strain as in the actual thermal environment. Both meteorological and non-meteorological (metabolic rate and thermal resistance of clothing) reference conditions were defined:

- wind speed (v) of 0.5 m/s at 10 m height (approximately 0.3 m/s in 1.1 m),
- mean radiant temperature (T_{mrt}) equal to air temperature,
- vapor pressure (VP) that represent relative humidity of 50%, at high air temperatures (>29 °C) the reference air humidity is defined as 20 hPa.
- representative activity to be that of a person walking with a speed of 4 km/h (1.1 m/s). This provides a metabolic rate of 2.3 MET (135 W/m²).

The adjustment of clothing insulation is a powerful behavioral response to changing atmospheric conditions. Thereby, the conception behind UTCI was to consider seasonal clothing adaptation habits of Europeans based on available data from field surveys, in order to obtain a realistic representation of this behavioral action.

The categorization of UTCI is based on physiological response of an organism at actual environmental conditions depending on the responses for the reference conditions and thermal load (i.e. heat or cold stress) (Tab. 3.7.2). UTCI values between 18 and 26 °C may comply closely with the definition of the “thermal comfort zone” supplied in the Glossary of Terms for Thermal Physiology (2003) as: “The range of ambient temperatures, associated with specified mean radiant temperature, humidity, and air movement, within which a human in specified clothing expresses indifference to the thermal environment for an indefinite period”.

UTCI (°C) range	Stress Category	Physiological responses
above +46	extreme heat stress	Increase in T_{re} time gradient Steep decrease in total net heat loss Averaged sweat rate >650 g/h, steep increase
+38 to +46	very strong heat stress	Core to skin temperature gradient < 1K (at 30 min) Increase in T_{re} at 30 min
+32 to +38	strong heat stress	Dynamic Thermal Sensation (DTS) at 120 min >+2 Averaged sweat rate > 200 g/h Increase in T_{re} at 120 min Latent heat loss >40 W at 30 min Instantaneous change in skin temperature > 0 K/min
+26 to +32	moderate heat stress	Change of slopes in sweat rate, T_{re} and skin temperature: mean (T_{skm}), face (T_{skfc}), hand (T_{skhn}) Occurrence of sweating at 30 min Steep increase in skin wetness
+9 to +26	no thermal stress	Averaged sweat rate > 100 g/h DTS at 120 min < 1 DTS between -0.5 and +0.5 (averaged value) Latent heat loss >40 W, averaged over time Plateau in T_{re} time gradient
+9 to 0	slight cold stress	DTS at 120 min < -1 Local minimum of T_{skhn} (use gloves)
0 to -13	moderate cold stress	DTS at 120 min < -2 Skin blood flow at 120 min lower than at 30 min (vaso-constriction) Averaged T_{skfc} < 15°C (pain) Decrease in T_{skhn} T_{re} time gradient < 0 K/h 30 min face skin temperature < 15°C (pain) T_{msk} time gradient < -1 K/h (for reference)
-13 to -27	strong cold stress	Averaged T_{skfc} < 7°C (numbness) T_{re} time gradient < -0.1 K/h T_{re} decreases from 30 to 120 min Increase in core to skin temperature gradient
-27 to -40	very strong cold stress	120 min T_{skfc} < 0°C (frostbite) Steeper decrease in T_{re} 30 min T_{skfc} < 7°C (numbness) Occurrence of shivering T_{re} time gradient < -0.2 K/h Averaged T_{skfc} < 0°C (frostbite) 120 min T_{skfc} < -5°C (high risk of frostbite)
below -40	extreme cold stress	T_{re} time gradient < -0.3 K/h 30 min T_{skfc} < 0°C (frostbite)

Tab. 3.7.1.2 UTCI equivalent temperature categorized in terms of thermal stress (Blażejczyk et al. 2010).

Following abbreviations are used: rectal temperature T_{re} ($^{\circ}\text{C}$), mean skin temperature T_{skm} ($^{\circ}\text{C}$), face skin temperature T_{skfc} ($^{\circ}\text{C}$), sweat production M_{skdot} (g/min), heat generated by shivering $Shiv$ (W), skin wettedness w_{etA} (%) of body area, skin blood flow V_{blSk} (%) of basal value, Dynamic Thermal Sensation DTS

3.7.2 Exemplary results

Thermal biometeorological conditions are described using the thermal indices PET and UTCI for Stuttgart. Thereby, the results are focused on the comparison of thermal indices and air temperature.

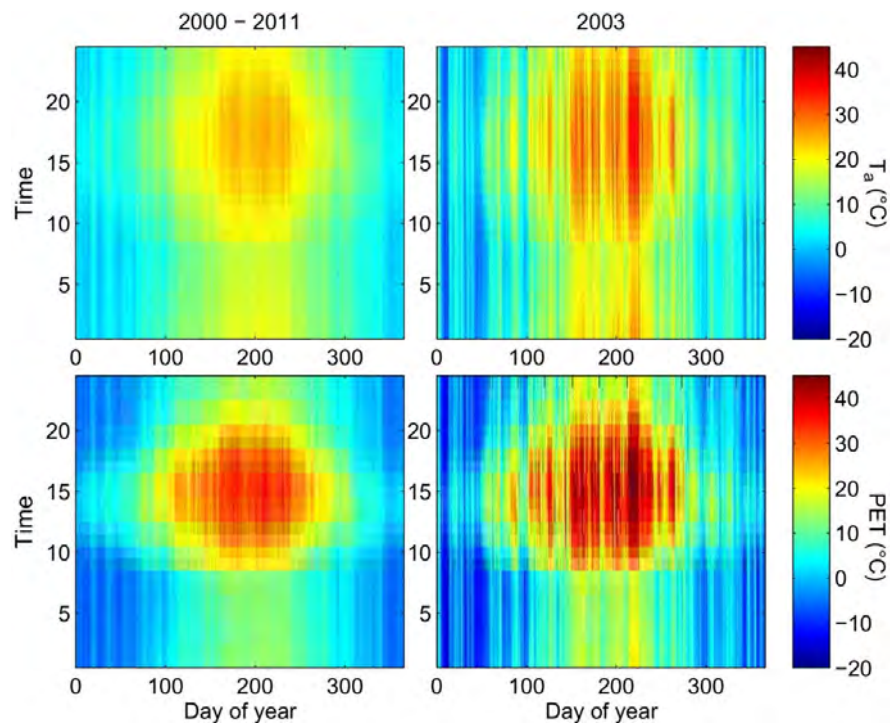


Fig. 3.7.2.2 T_a (upper graphs) and PET (lower graphs) for the period 200-2011 and 2003 for station Schwabenzentrum in Stuttgart.

Fig. 3.7.2.2 shows the air temperature conditions for the period 2000 to 2011 based on hourly data, where all the hourly data of the examined period is shown. A comparison is made between mean conditions and the specific year 2003, which experienced an extraordinary hot summer. The two upper graphs show the pattern of air temperature for the long period and the year 2003. It can be noted that, during summer 2003, air temperature exceeded very often the 30 °C level. This heat wave in 2003 had many negative effects on human health, which results in high mortality and morbidity rate in Western Europe (Koppe et al. 2003, Le Tertre et al. 2006). The daytime PET values are higher than T_a during the day. During the night, PET is lower than air temperature. During the winter, the values of air temperature are mostly higher than the values of PET, due to the effect of wind, low irradiation and air humidity.

Another possibility to describe thermal comfort conditions and urban rural differences can be the long terms analysis for different stations. In Stuttgart are located five stations and they have all been selected for the analysis (Tab. 3.7.2.3).

Measurement station	Lat (N)	Long (E)	Altitude (asl)	Feature
Neckartal (N)	48:47	09:13	224 m	River valley, urban
Schwabenzentrum (S)	48:46	09:10	250 m	City center, on top of a 25 m high Building
Schnarrenberg (Sb)	48:50	09:12	314 m	top of a SW-exposed hill
Hohenheim (H)	48:42	09:02	405 m	Suburb
Echterdingen (E)	48:41	09:14	371 m	Airport

Tab. 3.7.2.3 Location and altitude of the measurement stations.

Beanplots, developed by (Kampstra 2008), display the density curve of the data together with median or mean, percentiles or standard deviation. To obtain the typical bean shape, the density curve is mirrored along the central y-axis. Fig. 3.7.2.3 depicts beanplots for the described stations in Stuttgart (Neckartal, Schnarrenberg, Schwabenzentrum, Hohenheim and Echterdingen) for the period 2000-2011.

The plots show the seasonal pattern for winter, spring, summer and autumn for Ta (upper graphs), PET (middle) and UTCI (lower graph). The differences between the stations for Ta are small.

In particular, the daily minimum values are higher for the urban stations, compared to suburban site Hohenheim or the rural reference station Echterdingen. This fact can be explained by the heat storage in the city, but also by the differences in altitude, that reach more than 150 m.

The density distribution of PET is governed by radiation fluxes from spring to autumn, which is also the most impacting meteorological variable. In winter, the density distribution of PET is similar to the one of air temperature. Air temperature is the factor that influences PET most during winter.

The minimum values of UTCI (Fig. 3.7.2.3 lower panel) are lower than PET. This can be explained by adapting clothing model of UTCI during summer, but also by different assessment scale.

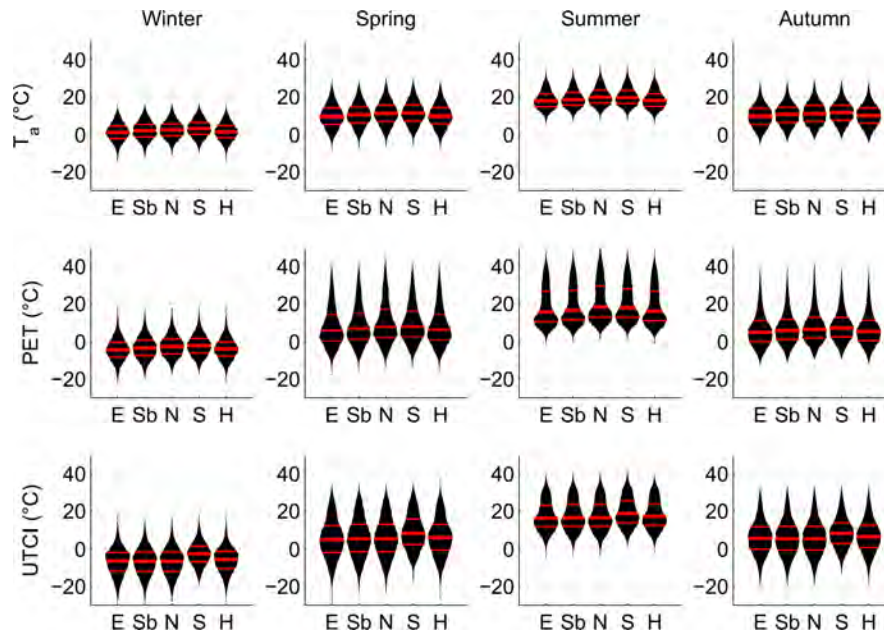


Fig. 3.7.2.3 Bean plots for air temperature (upper graphs), PET (middle graphs) and UTCI (lower graphs) for the Stations Echterdingen (E), Schnarrenberg (Sb), Neckartal (N), Schwabenzentrum (S) and Hohenheim (H) for the period 2000-2011.

In some cases, esp. for application in planning or for the detection of extreme events for human health, issues conditions can be analyzed in terms of thresholds of air temperature or any thermal index. Tab. 3.7.2.3 shows the amount of days per year for different levels of maximum air temperature ($T_{\text{amax}} > 30$ and > 35), minimum air temperature ($T_{\text{amin}} > 18$, > 20 and > 23), the conditions for the maximum value of PET ($\text{PET}_{\text{max}} > 30$, > 35 and > 41) according to the assessment classes (Tab. 3.7.2.1) and also the PET_{min} for the levels of > 18 . It can be seen that there is a difference in the conditions for maxima over $T_{\text{a}} > 30$ and only 1 or 2 days for $T_{\text{a}} > 35$ °C. In addition, it can be seen that T_{amin} conditions over > 18 and > 20 occur mostly in the urban area. Maximum values of PET are represented by a similar picture; however, the PET is generally higher than air temperature, while extreme heat stress ($\text{PET} > 41$ °C) can occur in more than 20 days per year in the city stations. The daily minimum value of PET never exceeds the threshold of 18 °C in Stuttgart (the frequency is below 0.1%).

	Echterdingen	Schnarrenberg	Neckartal	Schwabenzentrum	Hohenheim
$T_{\text{amax}} > 30$	8	13	10	14	7
$T_{\text{amax}} > 35$	1	2	1	2	1
$T_{\text{amin}} > 18$	3	15	11	20	6
$T_{\text{amin}} > 20$	0	4	2	6	1
$PET_{\text{max}} > 30$	93	85	96	99	92
$PET_{\text{max}} > 35$	55	57	58	61	54
$PET_{\text{max}} > 41$	16	26	19	23	15
$PET_{\text{min}} > 18$	0	0	0	0	0

Tab. 3.7.2.3 Number of days on which defined thresholds are exceeded.

Beyond the information given by the amount of days that manifest specific events, the amount of hours can describe more precisely the occurrence of specific conditions, thus providing more valuable information. Tab. 3.7.2. 4 depicts the total amount of hours for the thresholds for the examined stations in Stuttgart urban and rural area. It can be clearly observed that the amount of hours for T_{a} and PET is quite higher in the urban areas than in the rural one, esp. for $T_{\text{a}} > 35$ and $PET > 41$ during day time (10 to 16 LST). At nighttime (22 to 6 LST) the picture is a clearer indication that urban areas are quite hotter than rural areas.

	Echterdingen	Schnarrenberg	Neckartal	Schwabenzentrum	Hohenheim
Daytime (10 - 16)					
$T_a > 30$	40.2	53.6	70.5	76.5	37.5
$T_a > 35$	2.3	4.6	7.5	7.2	2.3
$T_a > 41$	0.0	0.0	0.0	0.0	0.0
PET > 30	534.5	560.3	539.3	587.4	522.5
PET > 35	252.9	271.2	298.0	289.9	244.4
PET > 41	54.9	64.4	97.7	75.1	51.6
Nighttime (22- 6)					
$T_a > 18$	11.9	44.6	52.5	121.0	27.1
$T_a > 20$	4.3	17.5	21.5	61.5	10.1
$T_a > 23$	0.4	3.9	4.4	21.5	2.1
PET > 18	188.5	305.2	292.8	516.6	277.4
PET > 20	75.0	149.4	154.0	307.5	130.5
PET > 23	12.4	36.3	40.5	115.0	29.6

Tab. 3.7.2.4 Number of hours per year on which defined thresholds were exceeded in the period 2000-2010.

3.7.3 Discussion and conclusion

There is an increased demand for the quantification and the assessment of the Urban Heat Island (UHI). Most of the studies deal with the comparison of different station in urban and rural areas based on different temporal resolutions and many studies report about differences in air temperature about maxima of more than 10 K and for mean conditions about 2 -3 K (Ketterer & Matzarakis 2014). In fact, cities are warmer than rural areas and the formation of the UHI depends mostly on energetic aspects of the urban structures. Most influencing factors are the limited horizon, the storage of heat of urban fabrics and anthropogenic heat emissions (Landsberg 1981, Oke 1982). There are several aspects to quantify UHI beside the energetic aspects (heating and cooling) and air pollution. Recent studies focus on the reduction of UHI based on the modification of urban structures, using

reflective materials or increasing evaporative cooling, however, these studies are mostly focusing only on some aspects of the energy budget of the urban areas and concentrate only on air temperature reduction. This aim is achieved using models with different spatial resolutions and designing exemplary measurements for case studies. All these results and information are demanded and can have a direct application. However, it has to be mentioned that results of thermal indices (PET or UTCI), compared to studies based only on air temperature, produce different outcomes. For example, increasing albedo of urban surfaces can decrease air temperature, but at the same time it increases the values of PET, due to increased shortwave reflection. This is a relevant topic not only during summer, but throughout the all year, because it affects the use of the urban spaces, where people want to spend time outdoors.

Finally, easy understandable graphs and figure are a possibility for better communication between different users and disciplines.

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Chapter 4

Decision Support Systems for urban planning

Emilia Romagna Region-General Directorate Territorial and negotiated planning, agreements

Democenter-Sipe Foundation

Abstract Decision Support System (DSS) is an interactive software-based tool that has been realized in the framework of the project “ Development and application of mitigation and adaptation strategies for counteracting the global Urban Heat Islands phenomenon (UHI) implemented through CE programme 2007-2013 co-financed by the ERDF.

DSS is a simplified database management tool that allow the use of the project deliverables uploaded on the web sites with a user-friendly approach. Users can access to the needed project’s output through knowledge’s needs oriented pathway.

Keywords Decision Support System,UHI, Mitigation actions, Urban planning, Climate change

4.1 Introduction

The construction of Decision Support System (DSS) has been realized in the framework of the Work Package 6 (WP6), in particular with the action 6.1.

The main activity of the WP6 was the UHIs simulation of future alternative scenarios related to the development of the urban areas chosen for the eight pilot actions.

In addition, WP6 was intended to define and realize a set of support actions for fostering the implementation of urban & spatial planning strategies in each involved region.

In particular, it was foreseen a progressive integration of mitigation and adaptation strategies in current urban planning tools.

Furthermore, DSS is designed to address policies in actions of mitigation and adaptation in the framework of the Urban Heat Island phenomenon.

4.2 Development Of The Uhi Project's DSS

During the project implementation the partners agreed to choose the hypothesis described below:

A simplified database management tool that allow the use of the project deliverables uploaded on the web sites with a user-friendly approach.

In this case users can access to the needed project's output through knowledge's needs oriented pathway.

To manage the urban development it is compulsory to manage a multitude of purposes and address many different goals, often conflicting, to satisfy the needs of different stakeholders. This poses considerable challenges to policy makers and urban planner. The need for enhanced urban plan decision support systems is evident in the same complexity of the UHI phenomenon.

In the following paragraphs is described the operation of the DSS chosen within the project on UHI.

4.3 UHI's Decision Support System

4.3.1 Structure

The UHI DSS is composed by a structure of html, javascript and php files that allows, via communication with a database, the end users to remotely access the project deliverables produced by UHI partners. In fact, considering the type of files and its structure, the software is a website, that can be installed and run on any platform that provides services http and MySQL.

The logical structure of the files is likely:

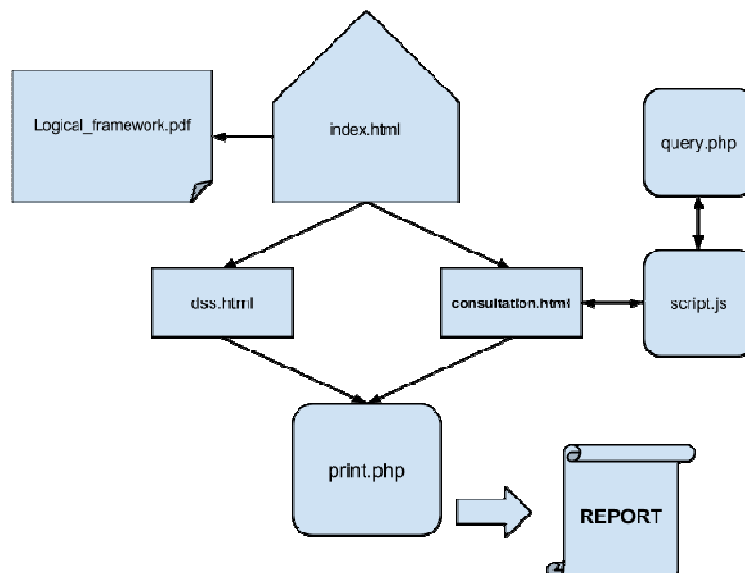


Fig. 4.3.1 UHI DSS Logical structure of the files

From the home page (index.html) you can access to:

- the logical framework of the project, which is a presentation of the UHI project; with a specific links to the official website of the project ;
- the Decision Support System, which allows, through a logical structure, obtaining a specific report based on the user's requests;;
- the Consultation Tool, which is a grid with specific questions about the results of the project deliverables produced by the partners; this tool is useful for users who know in advance what kind of information they are looking for.

The two php files (query.php and print.php) shall only be used to query the database that stores the data that is composing the report: in this case, query.php is part of the communication AJAX of the page consultation.html (through script.js); while print.php dynamically creates a page report based on the choices you make, whether they come from the DSS or from the Consultation Tool.

The database named db_dss_uhi is composed of five separate tables:

- intervention_type: stores data regarding the various types of intervention carried out in the pilot actions;
- legislation: containing the legislative framework for each region involved in the project UHI *;
- pilot_actions: the table with a detailed description of all pilot projects related to UHI project *;
- skills: the list (provided by partners) of the experts who have contributed to the UHI project with a short description of them and their personal contacts;
- software: a list of tools used by partners with a short description;

4.3.2 The interface

This paragraph shows the real functioning of the DSS as was finally built with the help of the below pictures.

The link of the DSS can be found on the homepage of the UHI website.

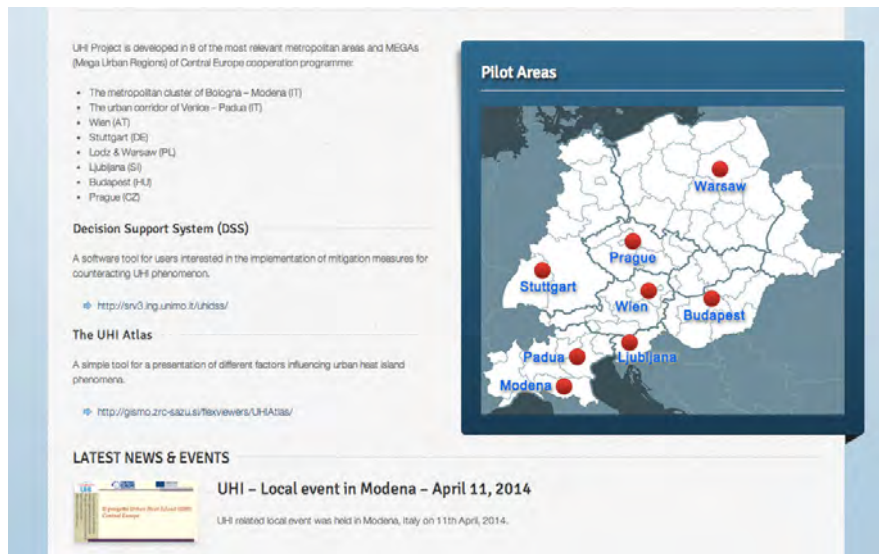


Fig. 4.3.2 UHI Project website

By clicking on the link highlighted above, the first page of the DSS appears like this:



Fig. 4.3.3 First page of the DSS

As the user can immediately see, from this page you can enter other three links to three different tools:

- Logical framework (magnifying glass)
- Consultation tool (open book)
- Decision Support System (right arrow)

4.3.3 Project Logical framework

Clicking on the left icon below, the user can have an overview of the entire UHI project.



Fig. 4.3.4 Link to the Project Logical Framework

As shown in the picture below in this page the user can find: a brief description of the project; the partnership; the framework analysis; the establishment of a UHI monitoring network; mitigation and adaptation strategies; pilot and capitalization actions for limiting UHI's effects.



Fig. 4.3.5 Logical Framework of the project

4.3.4 The Consultation Tool

The interface of the Consultation Tool consists of 7 menus, multiple choice or drop-down menu, in which user is asked to select some areas of interest.



Fig. 4.3.6 Link to the Consultation Tool

- Climate long term perspective, where the user can see through a map the following data:
 - change in annual mean temperature;
 - heat wave frequency;
 - changes in annual near-surface temperature.
- The Urban Heat Island phenomenon, where the user can select a city name in the drop-down menu between the various European cities that have been studied during the project:
 - Budapest;
 - Modena;
 - Warsaw;
 - Padua;
 - Stuttgart;
 - Ljubljana;
 - Wien;
 - Prague.

- Spatial and urban planning, where the user can, through the menu, select the following items of the interested area:
 - local rules and regulation;
 - incentives, financing, regulatory action;
 - E.U. rules and regulation.
- Mitigation strategies, where there is the possibility to choose the mitigation action you want to deepen and find out its benefits on UHI. This sub section is divided into three items:
 - Buildings
 - Cool roofs;
 - Green roofs
 - Green facades;
 - Facade surface and construction selection/retrofit;
 - Geometry of Urban Canyon.
 - Pavements
 - Cool pavements;
 - Pervious pavements.
 - Green areas
 - Planting trees within the urban canyon;
 - Park, green areas.
- Pilot areas, where the user can choose one of the eight pilot actions have been implemented that he wants to deepen:
 - Padua/Venice –Italy;
 - Modena/Bologna – Italy;
 - Wien – Austria;
 - Stuttgart – Germany;
 - Warsaw – Poland; Prague –
 - Czech Republic; Ljubljana – Slovenia;
 - Budapest – Hungary.
- Skills, where the user can choose the skill which is interested in:
 - Meteorology;
 - Biometeorology;
 - Urban planning;
 - Health;
 - Municipality;
 - Innovation;
 - Engineering;
 - Building skill;
 - Environment;
 - Communication.

- Simulation tools, where the user can, simulating the effect of a mitigation action in the urban area object of the pilot, choose the aspect that he is interested in deepening.
 - Global scale
 - Weather forecast;
 - Climate of your region;
 - Future climatic scenarios;
 - Weather risks for your region due to climate change.
 - Urban/district scale
 - Urban micrometeorology;
 - Influence of land use on urban climate;
 - Effects of street characteristics (orientation, width, buildings height, etc.) on urban climate;
 - Effects of urban topography on climate;
 - Influence of land use on urban climate;
 - Influence of different kind of roofs on urban climate;
 - Influence of different kind of pavements on urban climate;
 - Human perception of climate;
 - Knowing how land use influences the human state of wellness.
 - Building
 - Influence of different kind of roof on building;
 - Effects on micrometeorological variables due to different materials and properties of the building;
 - Influence of good/bad adopted measures on human health/wellness at building scale.

The following pictures show how are graphically displayed the contents above outlined.

Consultation tool

The tool will allow you to select your specific interest saving your time. The consultation will be easier and the needed material.

Climate long term perspective

To understand the different factors influencing urban heat island phenomena, please consult the UHI Atlas, a simple tool realized in the framework of UHI project. You are kindly invited to take a look at Central European Region and to see where areas that have higher air and land surface temperatures are located.

- Change in annual mean temperature (source: ENSEMBLES climate change project)
- Heat wave frequency (source: ENSEMBLES climate change project)
- Changes in annual near-surface temperature (source: ENSEMBLES climate change project)

The Urban Heat Island phenomenon (UHI)

In this project the Urban Heat Island phenomenon has been studied in various European cities, choose the one that interests you.

City:


Spatial and urban planning

Choose the regulatory framework in your area:

Area:

- Local Rules and Regulation
- Incentives, Financing, Regulatory Action
- E.U. Rules and Regulation

Fig. 4.3.7 The first three menus of the Consultation Tool



Mitigation strategies
The phenomenon can be investigated by applying specific mitigation actions; *Choose the mitigation action you want to deepen and find out its benefits on UHI.*

Buildings

- Cool roofs
- Green roofs
- Green facades
- Facade surface and construction selection/retrofit
- Geometry of Urban Canyon

Pavements

- Cool pavements
- Pervious pavements

Green areas

- Planting trees within the urban canyon
- Park, green areas

Pilot areas
In the project eight pilot action have been implemented; *choose the one you want to deepen.*

--area--

Skills
To accomplish the entire project, experts from throughout Central Europe worked together. *What skills do you need?*

- Meteorology
- Biometeorology
- Urban planning
- Health
- Municipality
- Innovation
- Engineering
- Building skill
- Environment
- Communication

Fig. 4.3.8 The subsequent three menus

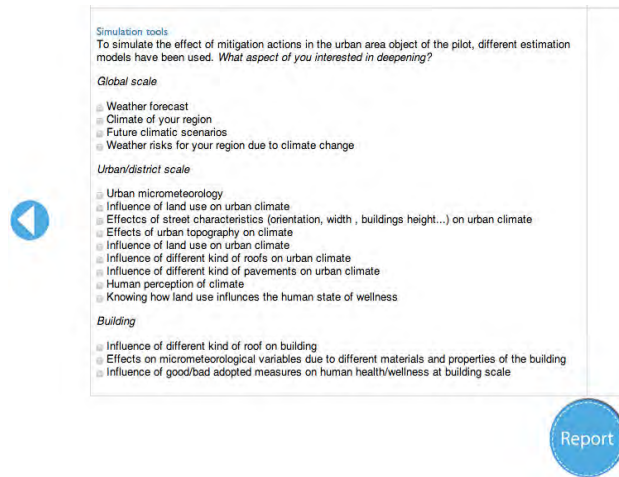


Fig. 4.3.9 The Simulation Tool

Once required the information requested by the user, the software searches in the documents produced in the WPs of the project the material/documentation or deliverable (re-organized in a logical framework); this content has been revised in order to obtain a final compact document with all the information selected. The results are finally displayed in html pages for instant opening for a quick reference, then the user can print it as a pdf.

4.3.5 The DSS

By clicking the icon in the middle of the screen, user is led within the DSS.



Fig. 4.3.10 Link to the UHI's DSS

By clicking on the different menu items the user can simulate the approach to his pilot study based on the data we gathered in our 8 pilot tests.

This section has 5 menus:

- Location: an interactive Central Europe Map allows the user to select the region of interest, as shown the picture below

Outline your pilot study
ision process, underlining the logical interaction between the different potential choices. In this case you'll be able to explore the project approach designing an healthy and sustainable city.



Fig. 4.3.11 Interactive Map

- Scale of intervention: the user can choose between two option, building or urban;
 - Typology of intervention: the choice here is between:
 - Menu item A)
 - Existing structure;
 - New construction.
 - Menu item B)
 - Facades;
 - Roofs;

- Surface lots;
- Urban structure;
- Urban green.
- Economic assessment: here the user can choose the action he would like to undertake between:
 - Cool roofs;
 - Green roofs
 - Green facades;
 - Facade surface and construction selection/retrofit;
 - Geometry of Urban Canyon.
 - Cool pavements;
 - Pervious pavements.
 - Planting trees within the urban canyon;
 - Park, green areas.

After entering a few data, the software proceeds a quick calculation of the action selected.

- Skills, where the user can choose the skill which is interested in:
 - Meteorology;
 - Biometeorology;
 - Urban planning;
 - Health;
 - Municipality;
 - Innovation;
 - Engineering;
 - Building skill;
 - Environment;
 - Communication;

The selections made in the menus help to match with the material presented above, relating them in a logical way.

This tool aims at presenting the same data of the Consultation Tool but in a more organic way: a combination of a raw data and documents selected shape a report and finally a model.

Indeed the choices are collected and reported in a final html page as a report.

4.4 DSS Input

The inputs of the DSS are all data stored in the database that contribute for processing the final information. In our case inputs are established based on the work developed in the previous Work Packages: WP3, WP4, and WP5.

From the above-cited WPs here follows a synthesis of the most important aspects necessary to set up the DSS.

4.4.1 WP3

WP3 was divided in 2 main actions:

- Action 3.1 was basically a review action in which one has collected different studies about the Urban Heat Island phenomenon. Action 3.1 was split in sub-actions. This analysis focused on anthropogenic causes that generate the UHI phenomenon and the survey techniques used to study it.

The analysis take into account both 1) technical-scientific issues and 2) urban planning and land use regulation.

1) Technical-scientific issues

- 1.a.reviewing knowledge (causes and related factors: anthropogenic causes that generate UHI phenomenon i.e. peculiar urban and building characteristics, particular industrial activities, etc.; the patterning of UHI phenomenon; the measures adopted to fight the intensification of UHI; the survey techniques used to study the phenomenon). Many relationships were found in literature to assess the UHI phenomenon based on different kinds of data.

Namely we have a collection of indices to establish the increase of temperature and the maximal increase of temperature based on:

- Population data;
- Urban geometric factors of buildings as well as infrastructures;
- Meteorological data.

- 1.b. scheduling of existing infrastructures to meteorological and environment data assessment in different project areas. A big range of methods can be adopted in order to study the UHI phenomenon. For each project area different data can be available. Based on this availability or lack of information DSS is able to provide as much as possible of accuracy in the results.

2) Urban planning and land use regulation

Urban planning and land use regulation assume an important role to regulate the possible actions of adaptation and mitigation. DSS take into account these in order to formulate answers. Of course these are not static and can be supported by the DSS to assess and to plan in a better way the urban development taking into account in particular:

- 2.a Review of different rules and regulation set up by involved local government (reviewing of the local main rules and regulations to plan the urban development and the land use; incentives and regulatory actions in support of environmental restoration, energy conservation and to fight climate change put in act from the different local authorities).
- 2.b. Review of the main European legislation concerning urban and spatial planning and concerned issues.
- Action 3.2. approaches the problem of UHI vs Climate Change: it aims to study the interaction between UHI and climate change phenomena as well as to understand the influences and correlations between them. Thanks to this Action have been set up indicators establishing relations among urban planning and human activities (main causes of UHI) with climate change trends, estimated on the basis of temperature shifting and other parameters. Regional climate model simulations are able to provide an estimation of the future climate scenarios (temperature, humidity, precipitation, wind speed,

cloud cover, etc.) which may serve as outer conditions for the assessment of UHI phenomenon in the CE cities. The simulations can be made with WRF, e.g., for a time slice of 10 years and statistical output on means and standard deviations of the meteorological variables can be supplied. Afterwards a downscaling to regional/town scales is required. Regional climate model uses available boundary conditions provided by existing global climate model. Climate change has the potential to alter shifts in average temperature, cloud cover, wind, speed and precipitation. The strong relationship between wind speed and cloud cover and UHI imply that changes in the magnitude of the UHI effect over the current century will depend at least in part on how cloud cover and wind speed change. Higher temperature might increase evaporation demand and may indirectly create a positive feedback, augmenting the temperature difference between city and rural setting. Though the magnitude of urban-suburban differences may not increase, the population affected by severe pollution episodes may increase as UHI-like conditions become more frequent in outlying suburban locations, presenting additional challenges for policy-makers.

In summary, tasks of WP3 were to provide the collection of techniques to assess the UHI phenomenon from which a selection have been chosen to be implemented in DSS. Moreover WP3 analyzes the European and local legislation within which decisions can be taken and from which DSS development is dependent.

Another important topic is the connection between UHI and climate change. Climate change will amplify the UHI phenomenon and its consequences for environment and human health have to be carefully taken into account. DSS has to consider then the projections to future scenarios to manage more useful information for administrators and stakeholders.

4.4.2 WP4

A large work to be implemented in DSS comes also from WP4 that is divided in three main actions.

- Within Action 4.1. a permanent Transnational Network (TN) among experts scientific and institutional involved was set up. TN monitors UHI in CE area; in addition it develops shared and coordinated strategies in urban planning and land using. Task of the Transnational Focus Groups was to manage the knowledge flow between partners and stakeholders and to share competence and knowledge on thematic issues with Local Working Groups.

- Action 4.2. Methodology and areas definition: definition of sensible indicators, sampling procedures and analysis tools are fundamental issues that need to be shared for a common methodology and compare different characteristics of urban areas. A gold standard in assessment of UHIs and in the respective data sampling, accessing and processing has been defined. Cities without a monitoring network suitable for monitoring UHI should take gold standard as a prototype in creating a new monitoring system. Cities with already existing monitoring systems was asked to adapt their systems to this gold standard, to allow a better coverage of phenomenon and to enhance the comparability between different cities.

- Action 4.3. CE UHIs web database and Atlas: the shared web databases implemented through input from existing local partners/institutions allows to monitor the specific situation. Here, the measurements and data obtained and analysed have been designed to describe as well as possible the intensity of phenomenon and its characteristics. Direct surveys conducted by applying both traditional urban biometeorology techniques and remote sensing techniques, allowed to collect many data and information about the micro-macro meteorological conditions. CE Atlas implementation foresees digitalization and geo-referencing of data collected. Creation of a GIS based data processing tool, where all information about detected UHIs of CE area where loaded and put in relation with meteorological and climatic data and trends as well as to spatial planning information.

In summary from WP4 we acquired for DSS the gold standard to define and to monitor UHIs with common and accepted rules. Moreover Act. 4.3 gave rise to the web database from which DSS will acquire information for model running.

4.4.3 WP5 Mitigation and adaptation strategies

Starting from scientific and institutional framework and from assessment tools provided by previous WPs 3, 4, WP5 was focused on approaches to model for long-terms mitigation strategies and short-medium-term adaptation strategies to encounter UHI.

WP5 deals with the following specific questions: Given the results of WPs 3 and 4:

What are the common and differential features of the UHI that effect the regions studied?

What set of mitigation and adaptation measures and options should be considered as potentially effective and subjected to detailed modelling studies?

How could "top-down" (low-resolution) meteorological prediction models and bottom-up (high-resolution) building models be combined to provide an environment modelling for parametric study of the aforementioned mitigation and adaptation measures and strategies?

Having identified a coupled top-down and bottom-up UHI modelling environment, what would be the outcome and implications (recommendations, guidelines) of the parametric modelling studies of alternative mitigation and adaptation measures?

Three Actions are developed in the WP5 framework: Act. 5.1, 5.2, and 5.3.

- Action 5.1. Extent of UHI effects and corresponding potential Mitigation and Adaptation (M&A) measures: Within the framework of this action, the common and differential features of UHI effects in the selected regions have been identified by the corresponding partners. A set of candidate (potentially effective) M&A measures have been collected and reviewed by the interdisciplinary and transnational research team. Thereby, the mitigation strategies provide the definition and application of urban& spatial-planning approaches (e.g. widening of green areas and rows, spread distribution of populated areas preferring short buildings surrounded by gardens, canyon effect) that prevent UHIs emergences. Likewise, relevant construction parameters for buildings (e.g. surfaces characteristics of external building components) have been considered. As to adaptation strategies, the phenomenon of summer bioclimatic discomfort has been addressed by setting up warning and prevention systems. Mitigation strategies, already mentioned in report 3.1.1., can be divided into three main categories, namely buildings, pavements and vegetation. For buildings one can work on directly either on their heat exchange material properties (valid for new and old buildings), or on the building/street geometry in order to modify the intensity of the so called canyon effect (valid only for new buildings). To the first category belong the following actions:

- Cool roofs/façades: By applying building materials with high solar reflectance (high albedo) and high infrared emittance (cool materials) one can reduce the cooling load of a building, and thus one can limit the heat emitted by the use of air conditioning facilities to the building's surroundings. Though cool materials can be applied for both roof and façade surfaces, it is usually easier and cheaper to apply them to existing roofs, making the method of "cool roof" creation more prevalent in daily practice.

- Green roofs: a green roof means a roof covered by a vegetative layer of variable width. Compared to traditional high absorptive roof surfaces, green roofs bringing about lower surface temperatures, thus leading to lower cooling loads in the building itself. Irrigation of these roofs can reduce the air temperature next to the roof, as an outcome of the evapotranspiration effect of the vegetative layer. When applied to a large group of buildings, green roof are believed to have a significant effect of urban air temperature.

- Green façades: vegetation can also be used as an overlying layer for facades, either by enabling the growth of climber plants directly on the façade surface (thus shading parts of it) or by

adding a more substantial bedding "wall" which connects to the façade and functions also as an insulating and evapotranspiration layer similar to that of a green roof.

- Street geometry, which is defined by the shape of the buildings and their orientation, might also have an impact on UHI intensity levels by increasing air flow rate through the street, thus replacing the warmer air "trapped" between buildings. Although changing the geometry of existing streets is limited, large urban projects regularly introduce the opportunity to increase the effects of advection by a careful design of their geometry.

- Pavements play also an important role in the formation of the UHI phenomenon, since conventional paving materials (mainly concrete and asphalt) tend to absorb large amounts of solar radiation during daytime and to release it to the cooler surrounding air (cool pavements). Another property of these paving materials is their limited permeability to water, which prevents the absorption of water in the ground and thus reduces the evaporation potential of the ground surface which may help in reducing air temperatures (pervious pavements).

- Cool pavements are built of materials which have higher albedo (higher solar reflectance) values than conventional paving materials, usually because of their lighter color.

- Pervious pavements: pavements of pervious materials which enable the draining of water through the porous pavement surface. The water is thus absorbed in the subsoil and evaporates when the paving material is heated, resulting in lower surface temperatures of the pavement. Pervious pavements are also helpful for the storm water management, and then for the prevention from floods.

- Vegetation: trees and vegetation reduces ambient air temperature by evapotranspiration and shading and is therefore expected to help in mitigating UHI intensity levels (Kurn et al. 1994). The common practices within this scope are the planting of trees and vegetation in existing urban fabric (mainly city streets), or the crea-

tion or preservation of wider green areas (parks, groves) within the urban fabric.

- **Action 5.2.** Establishment of an effective UHI modelling environment. The purpose of this action is to establish a coupled "top-down" (meteorological) and bottom-up (built environment) computational modelling environment. Thereby, low-resolution (large-grid) meteorological models provide data on large-scale UHI effects. This data are subsequently used as boundary conditions for medium-small scale thermal modelling tools of the built environment. For this scope, the potential of transfer functions has been explored. These functions derive from weather station data, high-resolution micro-climatic conditions at immediate proximity of built structures. The available simulation tools, used by the project partners are listed. These models and their coupling are the core of the DSS elaboration.

- **Action 5.3.** Definition of mitigation and adaptation strategies. Given the above coupled modelling environment, the relative performance (predicted degree of success) for various alternative M&A strategies and measures could be examined and numerically described. A set of strategies are formulated to be applied at national and transnational scales to address the UHI phenomena. Such M&A measures portfolio includes specific urban and spatial planning guidelines as well as risk management recommendations.

4.5 Main acronyms

CE: Central Europe

DSS: Decision Support System

LP: Lead Partner

WP: Work Package

AF: Application Form

UHI: Urban Heat Island

ACT: Action

DBMS: Database Management Software

MBMS: Model Base Management Software

DGMS: Dialogue Generation Management Software

SMS: Short Message Service

TN: Transnational Network

M&A: Mitigation and Adaptation

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Part II
Pilot actions in European cities

Chapter 5

Counteracting urban heat islands: solutions for European cities

5.1. Implementing solutions for climate change in urban context

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The effect of climate change on urban scale is often seen as a simple projection of a global risk. In fact, the urban environment is certainly characterized by particularly critical in relation to the effects of extreme events alluvial and heat waves, which is closely connected to the "climate change". In reality, however, the local and the global influence each other mutually shaping opportunities and constraints. In this sense, an integrated approach to mitigation and adaptation is the only way to reduce the impact of climate change and to turn a threat into an opportunity for sustainable territorial development, economic and social too.

Measures to reduce heat island effect in this regard are a prime example of an action that fits both the perspective of adaptation to climate change and their mitigation. Reduce hardship bioclimatic in urban involves not only the ability to innovate in terms of use of materials and construction techniques but also to change economic and social structures, ensuring over time the quality of life and the environment.

In this chapter we want to draw a picture of the relevance of the heat island phenomenon in relation to climate change and illustrate the potential of the interventions of urban planning. The urban heat island is certainly one of the best known effects of urbanization on local climate.

5.2 The Metropolitan Cluster Of Bologna-Modena

Emilia Romagna Region-General Directorate Territorial and negotiated planning, agreements

Municipality of Modena- Department of Territorial Planning and Private Building

ARPA-ER Regional Agency for Environmental Protection

Democenter-Sipe Foundation

Abstract The pilot action took place in a district of Modena, the Villaggio Artigiano, characterized by the presence of disused small industrial buildings, which is part of a wider redevelopment context and regeneration process.

The innovative mixture of instruments proposed by the Municipality to better re-use the territory and to estimate the environmental restoration achieved with the urban interventions, is a starting point to give the planner flexible and easy to use instruments.

Keywords cluster Bologna-Modena, Villaggio Artigiano, urban redevelopment, urban planning, urban indexes

5.2.1 Urban and environmental framework

Emilia-Romagna Region's territory, in the Padan area, includes the metropolitan area of Bologna and other main conurbations located in the Emilian area and in the coastal area. The first main urban conurbation develops from Bologna along via Emilia (Emilia Street), including the cities of Modena, Reggio Emilia up to Parma, and is characterized by high density settlements with high-intensity exchanges; the second one, distributed along the coastline, concerns the intensely built-up touristic area from Rimini to Cervia.

Emilia-Romagna's location makes it part of two National corridors which respectively connects the Apennine Mountains to the Adriatic Sea and North and South Italy, including: A1 and A14 highways, Piacenza-Rimini railway and a stretch of the high speed railway Milan-Bologna-Rome. Consequently, with a road network of 10.792 Km (which consists of 643 Km of highways and connection roads, 2907 Km of state roads and 7242 Km of provincial roads), the region has a key role for transport integration within National and European contexts.

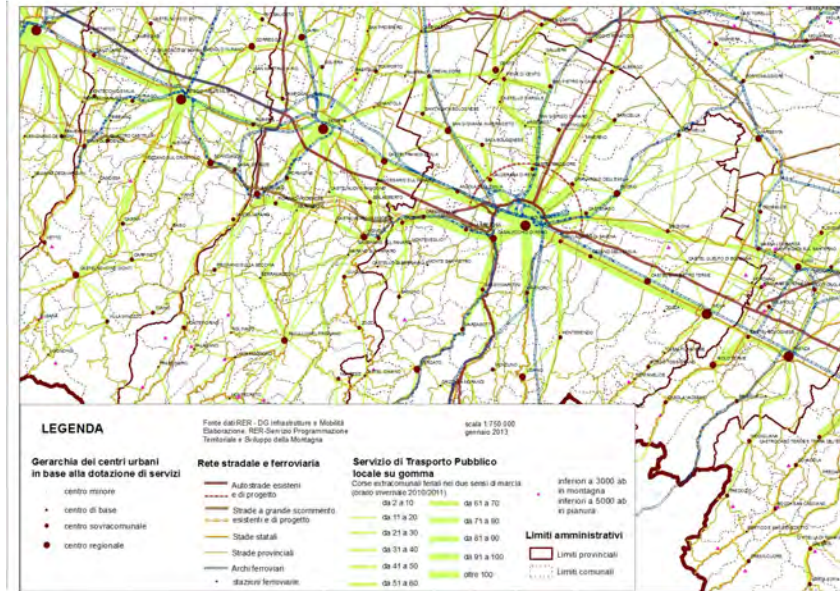


Fig. 5.1 Hierarchy of urban centres - Road and rail network

In the past forty years, a high intensity construction activity has affected the region and this has led to the spreading of settlements and of production and service sector activities. The main cities have lost inhabitants to the hinterland and consequently a sort of “city-area” characterized by a high and widespread urbanization index (153 inhabitant/kmq) has grown along via Emilia.

In addition to that, during the past twenty years Bologna’s metropolitan area has doubled, and the conurbations of central Emilia and along the coastline (where the 50% of the regional population lives), have been affected by an increase in urbanization and land consumption up to 8%-13% of the total surface.

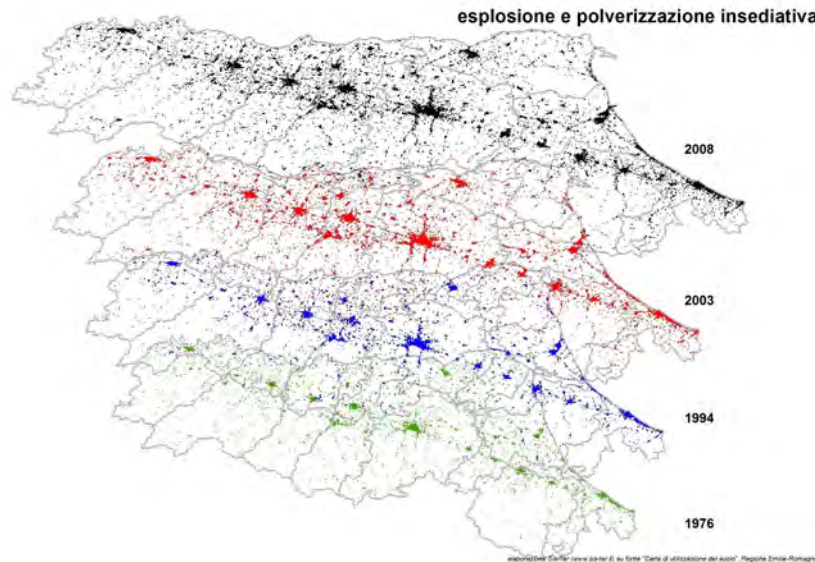


Fig. 5.2 Urbanization 1976-2008

The pilot area is located in the core of this regional system described above. It is among the more developed areas at the regional and European level as far as its socio-economic development is concerned. The three provinces of Bologna, Modena and Reggio Emilia host 56% of the regional industries. The local economy is based on the manufacturing sector, especially ceramic, which contributes to make Modena's province a key productive centre within Europe.

The presence of firms, together with service providers and houses, has a negative impact on road conditions and on the quality of life in the cities and it is the cause of polluting emissions reaching emergency levels for increasingly longer periods. The use of renewable energies in this area is also still low.

In the metropolitan cluster of Bologna-Modena, despite the presence of some of the bigger rivers in the region, the high density settlements (which characterize the area) have reduced the space for natural environment. Furthermore, the development of man-made infrastructures has a negative impact on landscape and creates more obstacles to policies aimed at (1) integrating the metropolitan areas of Bologna and Modena; (2) decongesting the central areas (along via Emilia) and (3) mitigating the environmental alterations linked to critical traffic conditions (air and noise pollution), which have negative consequences, especially on the health of children and the elderly; (4) improving the connection infrastructures and public transport.

The regional climate is sub-continental with strong difference between summer and winter: summers are hot and muggy and winters are cold, rainy, foggy, moderately snowy and long. On average, the temperature reaches minimum values at

dawn and maximum during mid-afternoon. Since 2001 an absolute maximum of 38,7° C and a minimum of -10°C has been detected.

The urban area of Modena is usually hotter and drier than the rural one. The biggest temperature differences are at night, and go from 2° to 8° C, especially in the summer.

Furthermore, while variations in humidity tend to be wider at night, they can also be quite considerable in the daytime, during the winter months.

During the last 20 years the climate has undergone a strong change, if compared to the period 1961-1990: the average temperature has increased (+1,1 °C) and so has the maximum temperature (especially in summer, + 2 °C) and changes have been registered with regards to seasonal cycles and the intensity of rainfall.

Issues such as the quality of the air, energy and water cycles, renewable energy and land consumption reduction have been set as priorities by the regional governments.

Appendix A contains rules and regulation set up by Emilia-Romagna local governments and Appendix B contains a summary of incentives, financing and regulatory actions implemented at local levels to facilitate a sustainable land use and to support environmental restoration, energy conservation and reduction of phenomena related to climate change.

5.2.2 Pilot area identification methodology and description

Emilia-Romagna Region has decided to select the pilot area of the "Villaggio Artigiano" (Craftsman Village) in Modena as the Administration was preparing the Municipal Operational Plan (POC prescribed by the regional planning law) called "Urban Redevelopment of the West Face of Modena", and expressed an interest in experimenting and integrating practical solutions aimed at containing the UHI phenomenon into urban planning.



Fig. 5.3 POC

In this framework, the Municipality of Modena has concluded the approval of a specific Plan of Urban Redevelopment of the Villaggio Artigiano

(<http://www.comune.modena.it/laboratoriocitta/laboratoriocitta/i-progetti-del-laboratorio/poc-mow>).

Given the new environmental context in which the Village is included, the plan entails interventions aimed at fostering high-performance at the overall urban as well as environmental systems.

The pilot action lies in the urban area of Modena, in the western sector of the city; this is an area which might have been considered “almost suburban“ until recently, but is now a rather central location of the city. Today, the Villaggio Artigiano is an area that is immediately identifiable by its unique triangular shape, framed by two streets coupling to the surrounding urban fabric and by the historical Bologna-Milano railway line.



Fig. 5.4 Villaggio Artigiano - Planimetry

The idea of the Village was conceived in 1954. Modena's municipal authorities decided to create a "craft area", after the economic crisis of the postwar period, with the aim of boosting the economic recovery.

The Council allocated 15 hectares of land to a "village for craftsmen" on the far western outskirts of the city, in the district Madonna.

Within six years, 74 new companies, their owners, new entrepreneurs (especially workers who had been laid off by large companies, people with specific expertise) found a place and started their trade in the wasteland between the railway and the Via Emilia.

Participation in the project, however, greatly exceeded the initial expectations of the Administration: the two triangular areas divided into 60 lots initially planned were immediately granted, the Village was then extended to the current size (almost 500,000 square meters), with about 200 businesses set up.

The "Villaggio Artigiano" presents a building structure that is rather recognizable even nowadays: perpendicular roads constitute a mesh with traditional orientation, deriving from Roman centuriation and subpartition of rural areas: 4 long streets are oriented from north-east to south-west and other shorter roads, orthogonal to the former, delimit all built lots.

The lots are all rectangular in shape. In the north, where the oldest portion of the Village is located, lot sizes are smaller, whereas those in the more recent south portion are larger.

The elements that make the Villaggio Artigiano a privileged project area today derive mainly from two sets of issues: one of an urban, economic and social nature, related to the ongoing problems of the area, and the other linked to the context of the Villaggio Artigiano and its strong, untapped potential.

In a nutshell, the themes considered in the redevelopment plan are:

- **Identity value** of the Villaggio Artigiano: it is a "piece" of the city history and an example of that "model Modena" that mainly contributed to the economic and social development of the city. For this reason, it is important, from the perspective of identity and business, to promote the renewal of the Village without compromising on its productive nature, and to boost the vitality of the area that seems to derive from the building typology and flexibility, which combines "home & shop" with very particular architectural languages.

- **Economic and entrepreneurial value**: seen in retrospect, and with a modern perspective, Villaggio Artigiano was a major help in what today is called the start-up of new businesses. To this one should add, the opportunity for artisans to have their houses built in the vicinity of their workshop, thus reducing significantly their personal and family costs of residence and transport. This particularly applies to the early settlements

- **urban planning value**: with regards to urban design and urban planning, the Village, located next to the Old Town, but also well connected to the extra-urban transport axes, is a center of gravity as far as the redevelopment of the whole western sector of the city is concerned. This feature will be greatly enhanced by new road connections and new forms of public transport. In fact, the Village is highly affected by the planned diversion of the railway line bounding the area, which will leave a large "diagonal" line of interconnection to the city center for new public spaces and transport services.

These features make the Village an ideal testing ground from the point of view of urban sustainability through the recovery of the existing fabric, ground-saving oriented, and the increase in the functional mix.

One of the main goals of this redevelopment plan is to renew the buildings in the Village, by means of a deep restructuring of the existing edifices, respecting the size and volume relations among them and producing a new estate body, which carries on and updates the typical evolution process of the Villaggio Artigiano.



Fig. 5.5 Villaggio Artigiano – Urban morphology

Therefore, the proposed regulatory actions are aimed at promoting the transformation of the Village, increasing the functional mix among production, which remains prevalent, services and residence, the latter to be rethought in new and experimental ways (home studio, new types of home-workshop, residential complexes with shared facilities etc.). In addition to these possible changes, on the public side, the main object of the redevelopment Plan is to redesign public spaces for meeting and socializing: rethinking and reorganizing the street mobility, creating parking areas and green spaces (using, for example, the large diagonal line on which the Village is grafted), signposting the presence of trade and services as an opportunity to generate significant spaces for urban quality of the neighborhood.

To date, the administration has launched a series of initiatives aimed at urban regeneration (buildings and public areas), as well as at economic and social improvement, summarized as follows:

- new urban-building rules;
- coordinated project for public space: the Village has its only public spaces in the streets, which have a very small section, are anonymous and not suitable for a non-automotive mobility. Through simulations and sectorial studies various options were examined for the transformation of the road network aimed to interconnect pedestrian, bicycle and automobile paths and to facilitate public accessibility and therefore the settlement of business and services.

- to exploit the dis-used railroad area, to be reinvented as "gateways" to the Village, as a large walk urban connecting two parts of the city historically divided; the Village has indeed a well-defined urban morphology, which makes it easy to identify, but it's also "closed" to the rest of the city.

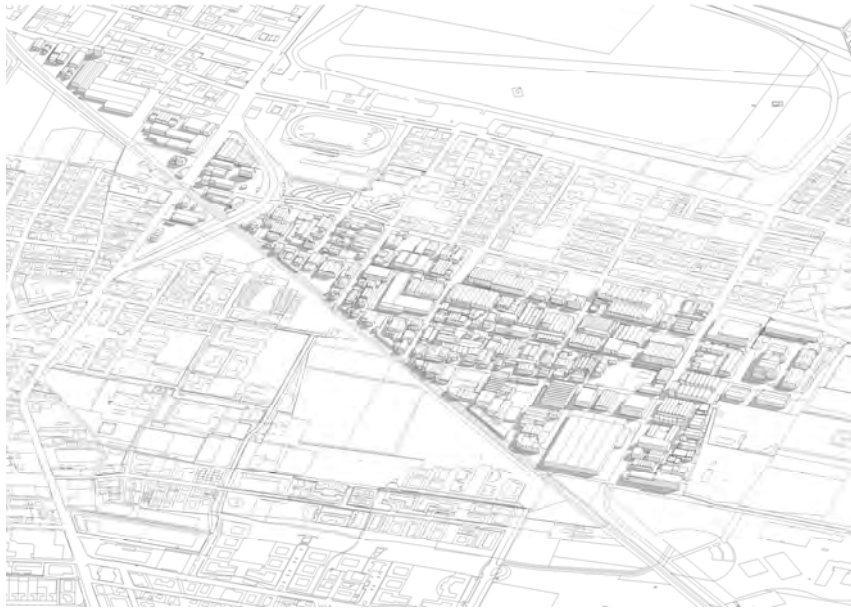


Fig. 5.6 Villaggio Artigiano – Planimetric view

Taking the modified environmental conditions of the area into consideration, the redevelopment plan aims to promote measures envisaging high-level performances, in order to ensure the environmental, as well as urban, upgrade of the area.

To counteract the alarming impact of UHI phenomenon the municipality of Modena began to consider the main environmental problems, to identify effective methods of construction.

The Plan aims to identify a synthesis of the main environmental issues related to the area of intervention, in order to derive a calculation method that can show the environmental performance achieved in the redevelopment of the individual lots.

The main environmental issues focalized in the Village are:

- reduction of the Urban Heat Island
- reduction of energy consumption
- reduction of the hydraulic risk

The “Artisan Village Guidelines” summarize the main features of the environmental method prepared by the administration. It is worth stressing that there are various analyses still under way for the final validation of various technical and procedural issues; as a consequence, although the structural characteristics have already been defined, the approach implemented may still be modified or emended.

In any case, the following items were thoroughly considered:

- Appropriate Building Massing:
- Energy Efficiency
- Passive strategies including: highly insulated; massing well arranged for summer radiation and also winter - optimized utilization of daylight, also using:
 - Buffer zones (such as winter gardens) to harvest passive solar energy and allow natural ventilation under cold/ windy conditions
 - External solar shading

5.2.3 UHI phenomenon in the urban area of Modena and application of models to simulate mitigation measures

Analyses on the UHI phenomenon in the urban area of Modena have been performed with a focus on the summer season. We compared data from stations located within the urban area and from stations located in the rural area. The findings showed that minimum temperatures in the urban area were higher than in the rural one. The differences between urban and rural minimum temperatures were generally larger during spring and summer, when they reached values up to 6°C. The highest intensities of urban heat island effect were found around midnight. On the other hand, the correlation between maximum values of temperature was the opposite: rural temperatures tend to be about 1°C higher than the urban ones. Relevant positive trends were present in the 30-year time-series of temperature. Long term trend of Heating Degree Days (HDD) and Cooling Degree Days (CDD) were also analysed (fig. 7-8). These parameters show to what extent the temporal trend of temperatures is either below (HDD) a predefined bioclimatic thresholds or above (CDD). A markedly decreasing trend was present in HDD time-series, while an opposite, less marked trend, appears for CDD.

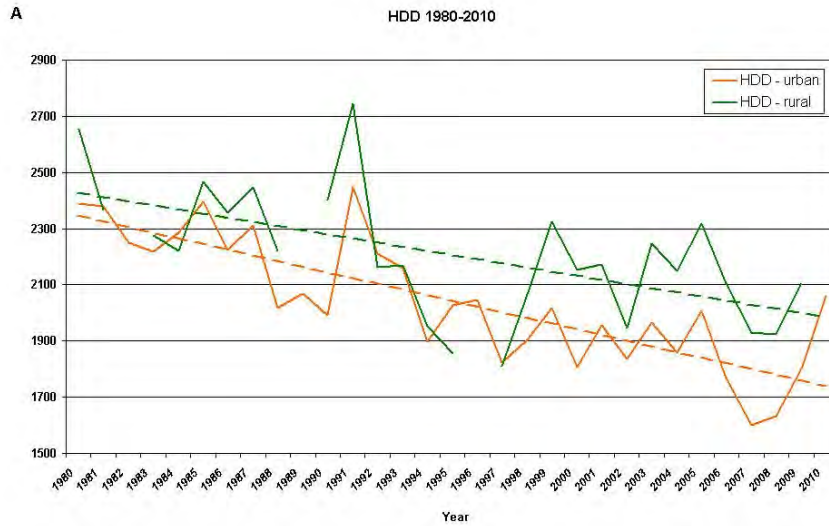


Fig. 5.7 Long term trend of Heating Degree Days (HDD) for the urban and the rural area

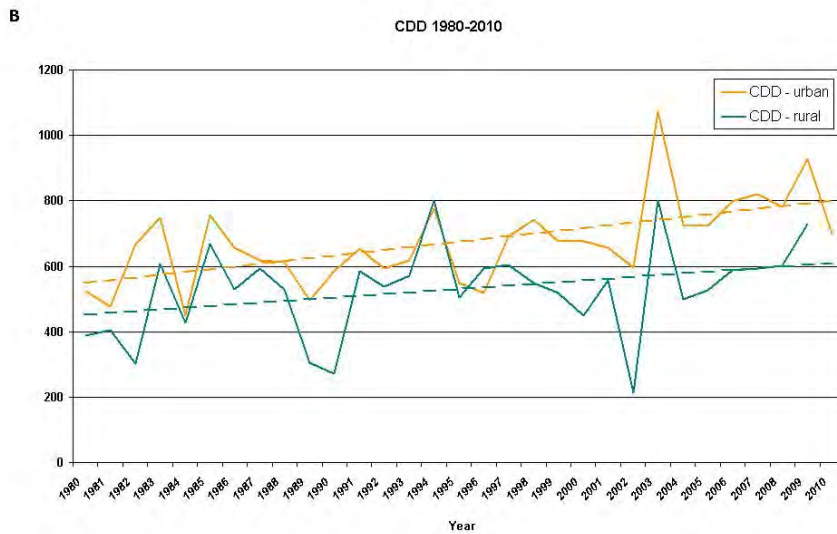


Fig. 5.8 Long term trend of Cooling Degree Days (CDD) for the urban and the rural area

Two main simulation tools have been applied to the pilot area in order to estimate the effect of some mitigation measures from a quantitative point of view. These simulations were aimed at assessing the effects of types of mitigation actions, and not the effects of specific interventions.

The first model applied in the pilot area was RayMan, a simulation model able to calculate short- and long-wave radiation fluxes inside a complex urban environment. Output from RayMan model consists in the values of several thermal indices derived from human heat-balance model. RayMan calculates the mean radiant temperature using a simplified radiation balance applied to a person which is exposed to:

- direct solar radiation;
- long wave radiation from ground, building walls and vegetation
- reflected radiation from the same surfaces.

In the present study, RayMan model was applied on a car parking area inside the Villaggio Artigiano. Firstly, the model was run for the actual situation in the domain (reference run) in a typical summer day in August. Then, some changes were introduced in the model domain (scenario runs) and the net effects of the mitigation measures on the thermal field and on the bio-meteorological conditions were estimated. A number of tests were carried out considering various combination of vegetation, type of materials for pavements and facades, height of buildings. From the point of view of thermal comfort, it was quite clear that most effective discomfort reductions were obtained introducing trees in the domain.

The shade from trees produced the largest impact and the mitigation effect was estimated in around 2 °C in the peak hours. A further point worth of notice is that, the pervious surface obtained by replacing the asphalt and/or concrete pavement with grass had a positive impact on the thermal comfort in its turn; however, the absolute value of this effect was much lower than in the scenario where trees were introduced, and the temperature reductions were below 0.5 degrees. Modification of building heights showed rather small differences in the values of bio-climatic indices.

The second model used to simulate the impact of different scenarios was ENVI-met, a three dimensional, non-hydrostatic model of the atmosphere, based on the fundamental laws of fluid-dynamics and thermodynamics. ENVI-met is a much more complex model than Rayman and is able to simulate the tri-dimensional field of the usual meteorological variables taking into account the interaction between atmosphere, urban surfaces and vegetation characterizing the complex urban fabric.

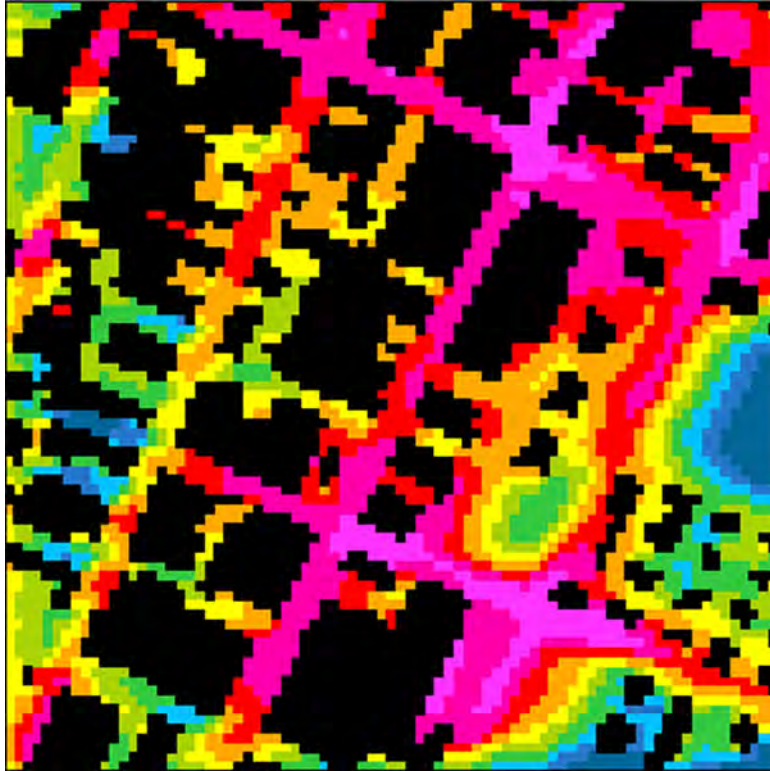


Fig. 5.9 Example of 2-meter height field of temperature as simulated by ENVI-met model

The model domain was a square of 400 m x 400 m, about a half of the whole Villaggio Artigiano (fig.9). The horizontal resolution was 5 x 5 meters (81 x 81 grid points). Vertical resolution was set to 3 meters, with the exception of the first model layers, which were split into 4 additional layers with the aim of showing a better representation of the interaction between the atmosphere and the surface elements. The simulation were run for the typical summer conditions for the city of Modena. Various mitigation measures were considered: insertion of green elements (grass and trees), change of the albedo of walls, roofs and pavements, insertion of pervious surfaces in substitution of asphalt and pavements. The findings showed a well-defined ranking in the impact of mitigation measures.

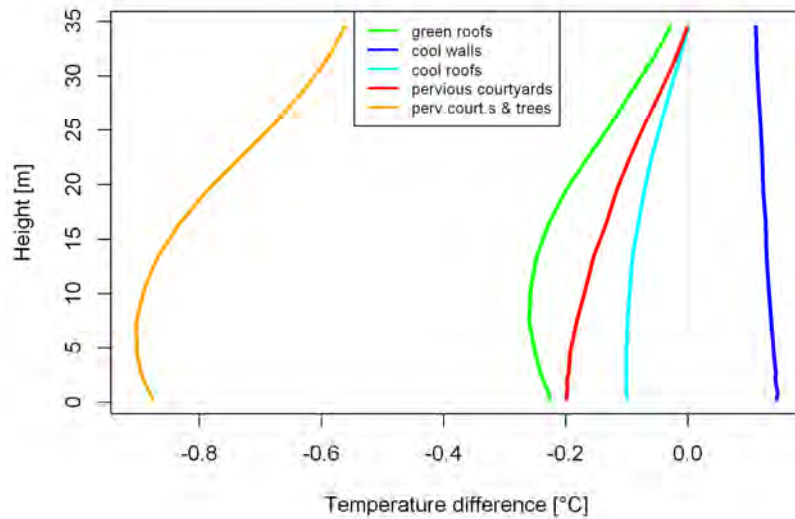


Fig. 5.10 Vertical profiles of "all day" mean differences between each scenarios, labeled as indicated in the legend, and the control run.

"Green courtyard with trees" was the most effective mitigation measure. A reduction of temperatures was evident for the entire course of the day. The "green roofs" scenario showed a peak of the cooling effect with respect to the control run at a height of around 10 meters, with a slightly smaller impact at ground level. On the contrary, "cool roofs" and "pervious courtyard" scenarios showed a peak of cooling at ground level with a relevant decrease of the impact going upwards. On the other hand, scenario with "cool walls" showed a negative effect in terms of mitigation of urban heat island. The cooling effect induced in this scenario was possibly explained by the unsatisfactory consideration of heat balance in model equation for buildings.

5.2.4 Experimental environmental quality index to assess the UHI's mitigation actions in a building lot

As described in the previous paragraphs, in the Villaggio Artigiano pilot area the following main environmental issues are taken into consideration:

- reduction of the Urban Heat Island
- reduction of energy consumption
- reduction of the hydraulic risk (not strictly connected to UHI phenomenon)

Starting from the experiences carried out by other cities, the Municipality of Modena decided to create a new calculation methodology, to be tested in the redevelopment of the Village.

Several municipalities are already equipped with calculation methodologies, in order to highlight the environmental performance achieved by the redevelopment of urban lots.

These calculation methodologies, also known as "urban indexes", are mainly focused on the urban impact created by the analysed phenomena, and are usually characterized by a simple algorithm.

The main existing urban indexes are the BAF, "Biotope Area Factor", used in Berlin, Malmo and Seattle, and the RIE, "Reduction of the Building's Impact", used in Bolzano and Bologna.

Both indexes calculate the ecological value of an urban lot.

Unfortunately, these indexes have limitations which make their application to "Villaggio Artigiano" impossible.

The Biotope Area Factor considers only the "green" surfaces and is therefore not suitable to assess the positive effect of a "cold roof".

The index of Reduction of the Building's Impact considers only the horizontal surfaces and is therefore not suitable to assess the positive effect of a "green" wall.

The main goal of Modena Municipality was to create a calculation methodology capable to:

- analyse all the surfaces that make up the urban lot, like the courtyard areas, building walls and roof,
- analyse different types of surfaces, like green or cool surfaces,
- stand up to existing indexes in terms of simplicity of data input,
- make appropriate approximations, like urban indexes typically do,
- highlight the environmental performance on the basis of indicators that predict physical tangible phenomena,
- implement procedures and values already defined by laws or municipal regulations.

The three main environmental issues (reduction of the Urban Heat Island, reduction of energy consumption, reduction of the hydraulic risk) have been linked to two indicators that have been used to derive two indices, the index "RATE" of

"reduction in the absorption of thermal energy" and the index "HYPER" of "reduction of hydraulic risk".

The creation of the index "RATE" followed four stages:

1. a list of types of surfaces that include the typical materials of the existing context and the materials used today in new projects.

Altogether 20 types of surfaces has been identified: 7 for the courtyard areas, 6 for the walls and 7 for the roofs. Some of these describe existing interventions, typical of the existing context, while others describe innovative interventions of recent use. The interventions that can be implemented in the courtyard areas are: garden or flower bed, tree or shrub, self-locking pavement, lawn driveway, "cold" asphalt, normal asphalt, gravel pavement.

The interventions that can be implemented in the walls of the building are: green wall with frame on wall, green wall integrated into the wall, ventilated wall with frame on wall, light plaster, dark plaster, wall with exposed brick.

The interventions that can be implemented on the roof of the building are: green roof, "cold" roof, tiled "cold" roof, photovoltaic roof, tiled roof, light flat roof, dark flat roof.

2. identifying a physical quantity, as an indicator, and a calculation methodology.

The indicator chosen to estimate the index "rate" is the thermal energy absorption of each surface of the lot, due to the incident solar radiation.

The absorption of thermal energy of a surface represents the amount of energy that that area is not able to reflect and disperse instantaneously, and therefore represents the amount of thermal energy that will be released for a certain period of time. The absorption of thermal energy is therefore able to highlight the capacity of a material to affect the Urban Heat Island.

In order to calculate the absorption of thermal energy a formula is used, which correlates the technical and physical characteristics of a surface with the incident solar radiation.

The technical and physical features used for the calculation of a generic surface, are: solar reflectance, emissivity and thermal resistance.

The index "RATE" calculates the sum of the absorption of thermal energy of all surfaces that constitute the urban lot.

3. analysing the technical and physical features of every surface in the list and of the existing context, to estimate the indicator. For each of the 20 types of interventions, the respective values of solar reflectance, emissivity and thermal resistance have been estimated. As for walls and

roof, different values of thermal resistance have been calculated, depending on the year of construction.

To quantify the incident solar radiation, the values defined by the norm UNI 10349 are used. Municipality of Modena has obtained a value to be applied on the roof and different values to be applied to the walls, depending on their orientation. Regarding courtyard areas, an average value was estimated, taking into account the loss of energy caused by the shading by building volume.

4. adopting the typical/needed approximations of urban indexes.

The Artisan Village Guidelines “Feasibility study of environmental quality indexes to be applied to building lots”, made by Municipality of Modena, are attached in appendix C and the link to the calculation software can be found on the website of the Municipality of Modena:

<http://www.comune.modena.it/laboratoriocitta/laboratoriocitta/pubblicazioni-eventi/villaggio-artigiano-di-modena-ovest/esiti-del-progetto>

and on the website of the Emilia-Romagna Region:

<http://territorio.regione.emilia-romagna.it/programmazione-territoriale>.

5.2.5 Adaptation Strategy to Heat Risk: assessment of a possible development of the heat risk alert system based on the use of emergency ambulance data

Increased temperatures and extreme heat can lead to a rise in mortality. In EU countries, mortality is estimated to increase by 1-4% for each one-degree rise in temperature, meaning that heat related mortality could rise by 30 000 deaths per year by the 2030s and 50 000 to 110 000 deaths per year by the 2080s.

As regard to the National level the Ministry of Health, in cooperation with the Ministry of Civil Protection, an "Early warning national system to prevent heat waves" has been operating since 2004, after the terrible summer of 2003. Furthermore, in 2005 a "National Operational Plan to prevent effects on human health from heat waves" was issued, and in 2006 "Guidelines to prepare monitoring plans in order to respond to heat waves" were provided to assist local authorities:

<http://www.salute.gov.it/emergenzaCaldo/paginaInternaMenuEmergenzaCaldo.jsp?id=413&menu=strumentieservizi>.

In coordination with national plan in Emilia-Romagna, a risk prevention local plan was designed and implemented to reduce the risk of damage and casualties due to summer heat waves.

Every year the plan guidelines are updated by the Emilia-Romagna Regional Government while ARPA (Regional Agency for Environmental Protection) issues forecasts throughout the summer.

The adaptation action then consists of:

- **Alert system** managed by ARPA, alerting when temperature and humidity level raise above a risky threshold
- **Emilia-Romagna Regional Government coordination actions** to assist most exposed people groups.

Alert system

ARPA Emilia-Romagna has been endeavouring to provide forecasting systems of some environmental risk factors to local authorities for several years now. Among such factors, the prediction of heat waves has gained relevance, particularly in relation to climate change projections for the coming decades.

The heat waves forecast service has been operating since 2004. ARPA Emilia-Romagna manages a specific website platform : <http://www.arpa.emr.it/index.asp?idlivello=97>

The forecast service is active between 15 May and 15 September. The forecast is done with 72 hours forewarning.

The Risk Alert alarm is based on the Thom’s Discomfort Index (DI). DI is a measure of the reaction of the human body to a combination of heat and humidity

	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%	THOM'S DISCOMFORT INDEX	
42°	32	32	33	33	34	34	35	35	36	36	37	37	38	38	39	39	Up to 21	No discomfort
41°	31	30	32	33	33	34	34	35	35	36	36	37	37	38	38	39	From 21 to 24	Less than half population feels discomfort
40°	30	31	31	32	32	33	33	34	34	35	35	36	36	37	37	38	From 25 to 27	More than half population feels discomfort
39°	30	30	31	31	32	32	33	33	34	34	35	35	36	36	37	38	From 28 to 29	Most population feels discomfort and deterioration of psychophysical conditions
38°	29	30	30	31	31	31	32	32	33	33	34	34	34	35	35	36	From 30 to 32	The whole population feels an heavy discomfort
37°	28	29	29	30	30	31	31	32	32	33	33	33	34	34	34	35	Over 32	Sanitary emergency due to the the very strong discomfort which may cause heatstrokes
36°	28	28	29	29	30	30	30	31	31	32	32	32	33	33	33	34		
35°	27	27	28	28	29	29	30	30	30	31	31	31	32	32	32	33		
34°	26	27	27	28	28	29	29	29	30	30	30	31	31	31	31	32		
33°	26	26	27	27	27	28	28	29	29	29	30	30	30	31	31	31		
32°	25	25	26	26	27	27	27	28	28	29	29	29	30	30	30	30		
31°	24	25	25	26	26	26	27	27	27	28	28	28	29	29	29	30		
30°	24	24	24	25	25	26	26	26	27	27	27	28	28	28	29	29		
29°	23	23	24	24	25	25	25	26	26	26	27	27	27	27	28	28		
28°	22	23	23	23	24	24	25	25	25	25	26	26	26	27	27	27		
27°	22	22	22	23	23	23	24	24	24	24	25	25	25	26	26	26		
26°	21	21	22	22	22	23	23	23	24	24	24	24	25	25	25	25		
25°	20	21	21	21	22	22	22	23	23	23	23	24	24	24	24	25		
24°	20	20	20	21	21	21	22	22	22	22	23	23	23	24	24	24		
23°	19	19	20	20	20	21	21	21	21	22	22	22	22	23	23	23		
22°	18	19	19	19	19	20	20	20	21	21	21	21	22	22	22	22		

Fig. 5.11 Thom’s Discomfort Index table.

This index combines the values of humidity and temperature parameters to describe the conditions of physiological discomfort due to heat and humidity. The

threshold of bioclimatic discomfort used for the Alert system were identified through a study of mortality conducted in the urban area of Bologna for the years 1989-2003.

– Weak discomfort

Weak discomfort conditions are defined when DI average daily value is 24. Under such conditions, the population feels discomfort but there are no increases in mortality.

– Discomfort

Discomfort conditions are defined when DI average daily value is 25. Under these conditions the weaker sections of the population, and especially the elderly, may experience health effects of various kinds, including headaches, dehydration. Such symptoms may cause fatalities in some extreme cases. The total mortality, natural causes and cardiovascular diseases increase on average by about 15%, and mortality from respiratory causes up to 50%.

– Strong discomfort

Strong discomfort conditions are defined when DI daily average value is 26 (the average daily index values never surpass this mark) or when an index level more or equal to 25 persists for 3 or more days. Under these conditions the categories of persons suffering from heat-related illnesses increase. The total mortality, natural causes and cardiovascular ailments, rise by an average of about 30%. The mortality from respiratory causes raises of about 80%.

Every day the system automatically alerts all concerned institutions (Healthcare District Services, Civil Protection...) via an email. The email states ALERT or NO ALERT in the object field, depending on if the DI is higher or equal to 24, or if it is lower than 24. Then the email itself specifies the Discomfort Level forecasted.

The following graphics show as an example the trend registered in 2012 and the one registered in the very hot summer in 2003.

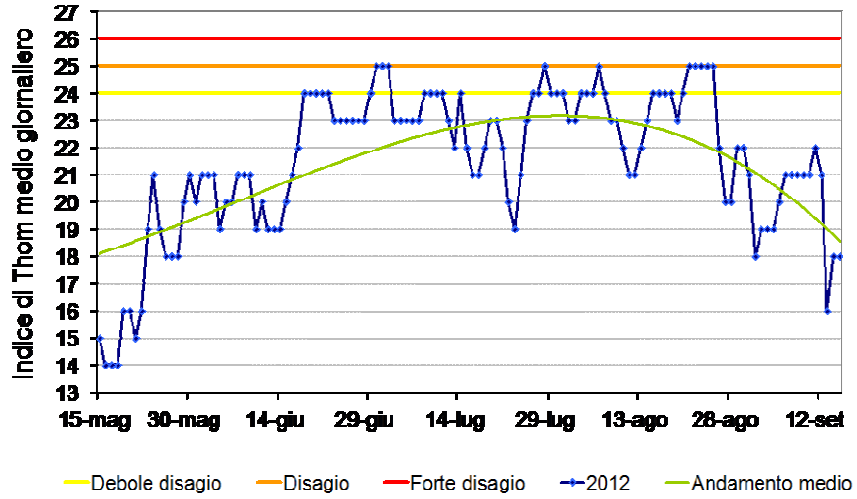


Fig. 5.12 DI trend registered in 2012

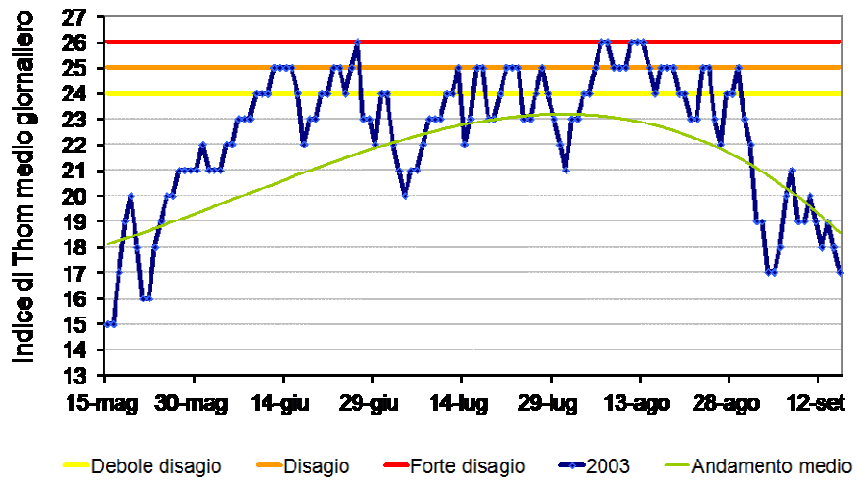


Fig. 5.13 DI trend registered in 2003

Emilia-Romagna Regional Government coordination actions

Emilia-Romagna Regional Government coordinates actions to assist people groups who are most exposed to heat waves, through Health Care regional system, Civil Protection, non-profit sector. These actions are activated by the ARPA alert system and they include two main activities:

1. Home care assistance:
 - Set up and coordination of Local Networks of all the actors involved in home care assistance, i.e.: Local Health Authorities (AUSL), City Councils, Voluntary associations;
 - Map High Risk Groups to be monitored during Heat Waves Alert, i.e.:elder people [>75 Y/old] living alone at home (in particular Local Health Authorities are obliged to notify all cases of elder people discharged from hospital in summer period and living alone), disabled people;
 - To strengthen home care assistance services, using all possible collaborations with Civil Protection volunteers and non-profit associations active in welfare.
2. Information actions

It has been shown that information on potential threats can be extremely useful in preparing the public for adverse events, as well as facilitating the response when such events occur. Starting from this assumption, a strong effort has been dedicated to produce an effective communication to citizens regarding heat waves effect on health and practical suggestions to prevent heatstroke.

In particular specific information contents have been prepared on:

- Heat effect on Health: direct effect (sunstroke, heatstroke, heat exhaustion, heat cramps), indirect effect (i.e. health condition worsening of people weakened by physical or psychological diseases), risk groups (elderly people, children, people affected by specific diseases – diabetes, cardiovascular disease..);
- Practical suggestions to prevent Heatstroke: telling how to limit the discomfort (what to eat/drink and what not, most dangerous day time, how to dress, how to manage home air conditioning..); telling what to do in emergency case (symptoms, 1st aid, who to call..). All this information are spread out both through the specific web platform on Heatwave managed by ARPA ER (<http://www.arpa.emr.it>) and through specific awareness campaigns managed by Local Health Authorities, addressing the specific high risk groups. (i.e. leaflets have been created by local health governments and addressed to home care staff, informing them on what to do in case of heat waves, what to eat, how to dress, relation with medicines, how to behave at home and outside, early warning signs of a heat stroke).

Proposed Pilot Action: preliminary assessment of a possible development of the heat risk alert system based on the use of emergency ambulance data

The suggested pilot action aims at verifying a possible improvement of the Heat Risk Alert System currently operational in the Emilia-Romagna region. The development would be based on the use of emergency ambulance data.

Today the discomfort index threshold levels have been identified via epidemiological analysis based on historical mortality data. A study developed by Arpa on all most important cities of the Emilia-Romagna region, except Rimini, evaluated the exposure–response curve of ambulance dispatches in relation to biometeorological conditions using time series techniques showing a strong correlation between ambulance dispatches increase and apparent temperature. The effects of high temperatures on health were evaluated for respiratory and cardiovascular diseases as well as for all non-traumatic conditions.

For apparent temperatures lower than 25°C, ambulance dispatches were not affected by changes in biometeorological conditions. Above that threshold, an increase of ambulance dispatches associated with respiratory diseases has been found, while cardiovascular diseases remained unaffected by variations in apparent temperature. For apparent temperatures higher than 30°C, the percent increases associated with each unit increment of apparent temperature became very high, with the main effect seen with cardiovascular diseases.

The findings of the study demonstrated the usefulness of ambulance dispatch data due to their strong link with heat and their real-time availability. As a matter of fact, these data are collected and stored with the same software and the same protocols across the region Emilia–Romagna, and are the only health data available in real-time.

Based on these reasons ARPA tried to test the possibility of the use of these data for a development of the heat risk alert system. The main goal of the analysis was to verify how strong was the relationship between bioclimatic discomfort conditions and increased ambulance dispatches across the Region on a daily basis.

ARPA defined as “alert day” a day when apparent temperature averaged among the main towns of the region is above 25°C. The expected number of ambulance dispatches for each summer day was calculated averaging the daily ambulance dispatches in a 15-day period centered in the selected day over the years 2003–2006 (excluding all the alert days from the computation); a standard deviation was also computed as a variability indicator. Days with a number of ambulance dispatches exceeding the expected number for that day plus twice the standard deviation were considered as days with an elevated number of dispatches (“case day”).

The strength of the correlation between case and alert days was tested using sensitivity, specificity and positive predictive value defined as follows.

		ON Alert Day (ONAD)		
		Yes	No	
Case Day	Yes	True Positive (A)	False Positive (B)	A + B
	No	False Negative (C)	True Negative (D)	C + D
		A + C	B + D	

$$\text{Sensitivity (Se)} = A/A+C$$

$$\text{IC}_{95\%(\text{Se})} = \text{Se} \pm 1.96 * \sqrt{(\text{Se} * (1 - \text{Se}) / n)}$$

$$\text{Specificity (Sp)} = D/B+D$$

$$\text{IC}_{95\%(\text{Sp})} = \text{Sp} \pm 1.96 * \sqrt{(\text{Sp} * (1 - \text{Sp}) / n)}$$

$$\text{Predictive positive value (PPV)} = A/A+B$$

$$\text{IC}_{95\%(\text{PPV})} = \text{PPV} \pm 1.96 * \sqrt{(\text{PPV} * (1 - \text{PPV}) / n)}$$

Sensitivity refers to the proportion of days showing elevated heat-related disease counts detected by the surveillance system during ON Alert Day - ONAD (reported cases correctly classified). Specificity refers to the proportion of days with normal numbers of heat-related diseases during Off Alert Day - OFAD. Positive predictive value (PPV) refers to the number of days with a significant count of ambulance dispatches during the ONAD among the total number of days with a significant count of heat-related ambulance dispatches. For example, a true positive is defined as the number of above-threshold days in terms of the number of ambulance dispatches during ONAD.

The first results of our analysis were

Sensitivity	0.19	IC95%(0.14, 0.26)
Specificity	0.97	IC95% (0.92, 0.99)
Positive predictive value	0.90	IC95% (0.76, 0.97)

These findings shows a correlation in terms of specificity and positive predictive value: in fact, almost every day in which an elevated number of ambulance dispatches occurred was an alert day, i.e. a hot day. In addition, the high value of specificity shows that almost no false positive are produced by the model. On the other hand, low sensitivity shows that a relevant fraction of alert days (i.e. hot days) doesn't imply a large number of ambulance dispatches.

We also tested the calculation of the same indicators in single towns. The average value of sensitivity, specificity and positive predictive value obtained across the region were 0.13, 0.97, 0.83, respectively.

These preliminary results confirm the usefulness of a surveillance system based on ambulance data. An additional level of alert for the health prevention system would be suitable when alert days are associated with exceptionally elevated number of ambulance dispatches.

The most appropriate spatial scale for the alert system (e.g. single towns, “area vasta”, whole region), a more sophisticated definition of hot days (with the inclusion of information on persistence), alternative definition of threshold values for apparent temperature are currently under investigation. The forthcoming availability of longer time series of ambulance dispatch data will also improve the robustness of the analysis.

The use of Ambulance dispatches to evaluate the risks associated with biometeorological discomfort has the following advantages respect the current use of mortality data:

- A higher number of data to correlate with Discomfort Index (10X), taking into account a wider range of the effect of heat on health.
- The ability to monitor the effect on health during heat episodes (real time monitoring)
- Additional information which can be gathered with ambulance dispatches (location of the calls) could allow spatial analysis to identify geographical areas at higher risk.
- A better categorization of diseases in ambulance dispatches could enable to better define effect of heat waves in human health (cardiovascular diseases, respiratory diseases..)

In conclusion, the encouraging results of this preliminary analysis point to the setting-up of a surveillance system, whose actual implementation should be arranged in cooperation with Health Authorities both at local and regional level.

5.2.6 Conclusions

The UHI project sought to boost transnational discussion among policy makers, local administrators and professionals in order to bring about developing policies and actions with the purpose of adapting and mitigating the natural and man-made risks arising from the UHI phenomenon. For this purpose the pilot action of "Villaggio Artigiano" was aimed at:

- providing a deeper knowledge on man-made risk of the UHI and its interactions with global climate change,
- setting up suitable strategies for the mitigation of - and adaptation to UHI,
- improving current land-use planning tools and civil management systems according to mitigation and adaptation strategies.

As explained above, the purpose of this case study was to find ways/rules that can mitigate and tackle the UHI phenomenon. Expected results are:

- mitigation of UHI phenomenon through the definition of appropriate construction requirements and standards (green roofs, reflective materials etc..) in accordance with urban quality,

- definition of guidelines to develop a specific project.

In this regard the Villaggio Artigiano is a suitable area to tackle UHI phenomenon, because it is part of a wider redevelopment context and regeneration process, strongly supported by public institutions and citizens.

The main objective of the regeneration plan is to allow a redevelopment of the housing stock in the Village, through a deep renewal of existing buildings, including demolition and reconstruction of a new building while maintaining the shape of the previous one, thus preserving the system of dimensional and volumetric relationships that characterizes the Village, and achieving a new building organism that continues and updates the typical evolutionary process of the "Villaggio Artigiano".

Given the new environmental context in which the Village is included, the plan entails interventions aimed at fostering high-performance at the overall urban but also environmental systems.

For this purpose, the Municipality of Modena has defined a set of environmental indexes focused on the assessment of 3 main affecting phenomena: the Urban Heat Island, the energy requirements and the hydraulic risk. Consequently, a new calculation methodology has been defined, to be tested in the redevelopment of the Village, capable to measure the environmental effects and the achievement of the planning targets and to estimate the benefit-cost ratio in the redevelopment of urban lots.

Identifying indexes to measure the multiple environmental effects of the urban transformations is the challenge for urban planners.

Next Steps

The City of Modena is collaborating with the EELab Department of the University of Modena, to refine the scientific approach adopted in the analysis of phenomena.

Furthermore, Modena is collaborating with engineers from ARPA, the Regional Agency for Environmental Protection, within the European project UHI, in order to analyze the correlation between types of intervention described in the index "rate" and the reduction of the Urban Heat Island phenomenon

The Municipality of Modena is awaiting the conclusions from the ongoing analysis, to finally validate the experimental indexes and put them into practice.

The indexes, evaluating the achievement of valuable solutions from the environmental point of view, could be useful to set the potential reward to be given to requalification projects. The municipality is considering to provide the use of the indexes within the redevelopment plan of the Village, so to regulate rewards,

through discount on the contribute for requalification, or through the introduction of “bonus” related to the architectural and urban value of the adopted interventions.

The urban indexes represent an experimental approach with huge potential, a starting point to give the planner flexible and easy to use instruments.

ANNEX A**Review of the different rules and regulation set up by Emilia-Romagna local government**

Resolution of the regional council n. 344 of 14th March 2011 “Directive 2008/50/CE of the European Parliament on ambient air quality and cleaner air for Europe put into effect by D. Lgs (legislative decree) n. 155 of 13 th August 2010 Request for extension of the deadline for accomplishment and dispensation from respecting specific limit values for nitrogen dioxide and PM10”
Resolution of the regional Assembly n. 28 of 10th December 2010
Resolution of the regional Assembly n. 1570 of 26th July 2011
Resolution of the regional Assembly n. 50 of 26th July 2011
Resolution of the regional Assembly n. 156 of 4th March 2008
Regional Law n. 26 of 23rd December 2004 “Discipline of the territorial energy planning and other energy related provisions”
Regional Energy Plan “PER” (Resolution of the regional Assembly n. 141 of 14/11/2007)
Regional Territorial Plan “PTR” (Regional assembly resolution

n. 276 of 3/2/2010)
Integrated Transports Regional Plan “PRIT” - 1998
Environmental Action Plan – 3/12/2011

Resolution of the regional council n. 344 of 14th March 2011 “Directive 2008/50/CE of the European Parliament on ambient air quality and cleaner air for Europe put into effect by D. Lgs (legislative decree) n. 155 of 13th August 2010 Request for extension of the deadline for accomplishment and dispensation from respecting specific limit values for nitrogen dioxide and PM10”.

This resolution passes the thematic cartographies regarding the areas in the municipalities where PM10 and NO2 value limits are exceeded. These cartographies are the knowledge basis used by the relevant authorities as far as the management of ambient air quality is concerned in order to detect and put in place the necessary actions to meet the limit values within the shortest period.

The resolution establishes that also the activities of regional planning must contribute to reaching the objective of air quality. Especially, as far as the definition of measures and interventions in the sectors of transportation, energy, industry, agriculture, construction and urban planning are concerned, Emilia-Romagna regional authority must take into consideration the necessity of meeting the limit values for nitrogen dioxide and PM10 as established by the Community laws.

Resolution of the regional Assembly n. 28 of 10th December 2010 for the implementation of the National Guidelines with regards to the identification of the areas available for installation of photovoltaic solar electrical plants. Regulation of the other kinds of renewable energy is intended to be addressed into a following resolution.

Resolution of the regional Assembly n. 1570 of 26th July 2011 “Identification of the areas available for installation of wind power, biogas, biomasses and water electrical plants”.

The national and Community legislator have stressed the importance of linking the principle of supporting the development of renewable energies to the other Community principle of land sustainable protection and enhancement in order to maintain the capacity of the territories of providing ecological, economic and social services and to maintain their functions, including the agricultural sector ones.

Resolution of the regional Assembly n. 50 of 26th July 2011 “Second three-year implementation plan of the Regional Energy Plan (PER) 2011-2013”. The first implementation of PER was carried out through the three-year plan 2008-2010, which was passed together with the PER itself (Resolution of the regional Assembly n. 141/2007).

The second implementation plan includes the objectives, commitments and programmes that have been agreed at the European and national level.

Energy efficiency and spare represent the first objective: Emilia-Romagna Region aims at building class A houses starting from 2014, at renewing the building stock, at reducing the emissions of motor

vehicles, at spreading the cogeneration and the systems of distributed energy generation, at recovering heat from production activities and making them more efficient. The other main objective of the second implementation plan is the development of renewable energy.

Resolution of the regional Assembly n. 156 of 4th March 2008 which passes the “Orientation Act about the criteria of energy performance and about the procedures for the certification of energy performance of buildings”.

Emilia-Romagna Region is one of the Italian regions which have fully and concretely implemented the Community directives on buildings energy performance.

This resolution regulates:

- a) The minimum qualifications for energy performance of buildings and of their energy plants
- b) The methodologies for the assessment of energy performance of buildings and of their energy plants
- c) The issue of the certificate of buildings energy performance
- d) The accreditation system of the building energy performance operators
- e) The maintenance of buildings and energy plants
- f) The regional information system for monitoring the energy performance of buildings and of their energy plants
- g) The measures supporting energy efficiency and the development of energy services for the regional population

The resolution was adopted according to: the Regional Law (L.R.) 20/00; art. 2 and 25 of the L.R. 26/04. It has implemented the provisions of directive 2002/91/CE and 2006/32/CE, also complying with the fundamental principles and the minimum performance standards set by the national legislator.

The provisions included in the resolution have come into force on 1st July 2008.

Regional Law n. 26 of 23rd December 2004 “Discipline of the territorial energy planning and other energy related provisions”.

This law promotes the sustainable development of the regional energy system and guarantees a matching among the energy which is produced, its rational use and the territory and environment carrying capacity.

Provinces are charged of:

- a) authorizing and implementing the energy spare and efficient energy use promotion plan, the promotion of renewable energies, the development of provincial energy plants and networks, also through the enhancement of existing buildings;
- b) authorizing the installation and the operation/practice of energy plants which are not covered by the State and regional scope.

Municipalities are charged of:

- a) authorizing programmes and implementing projects for energy qualification of the urban system, especially with regards to: intelligent energy use promotion, buildings energy spare, development of renewable energy plants, other actions and public services aimed at supply the demand of energy in urban areas, including district heating networks and public lighting also in the framework of urban regeneration programmes according to the current law;
- b) functions defined in art. 6 of law n. 10/1991, together with the other functions assigned by other specific laws.

Art. 5 “Tools for urban and territorial planning and adaptation of regulations on building issues” establishes that:

1. Local authorities operate through their tools of territorial and urban planning in order to guarantee the restraint of energy consumption in urban areas, promote renewable energies, promote the supply and usability of other energy related local services also in the framework of urban renovation interventions on existing buildings.
2. Territorial and urban planning:
 - a) set the energy local supply of public interest to be installed or renovated and the corresponding location
 - b) can decide to implement transformation interventions where there are infrastructures for renewable energy production, recovery, transportation and distribution or where their construction is planned
3. Municipalities, in the framework of their legislative powers on urban planning and construction activities, acknowledge the minimum qualifications for energy performance set by the regional council and can decide not to put them in place in case of the categories listed in art. 4 paragraph 3, directive 2002/91/CE.
4. Municipalities operate in order to:
 - a) in case of new urbanization interventions on a surface bigger than 1.000 mq, get the assessment of technical and economical feasibility for installing renewable energy plants, cogeneration, heat pumps, centralised heating and cooling systems;
 - b) in case of newly constructed buildings with centralised heating systems, requesting of putting in place systems for temperature control and heat accounting for each habitation unit;
 - c) in case of newly constructed public buildings or buildings used for public scopes, respect the obligation of using renewable energies and adopt electronic control systems;
 - d) in case of interventions according to art. 6 of the regional law n. 31 of 25th November 2002 (General construction discipline) on existing buildings with a surface bigger than 1.000 mq, improve their energy performance with the aim of meeting the minimum qualifications described in art. 25, para-

graph 1, letter a) of this law and of creating the conditions to put in place systems for heat accounting for each habitation unit.

Regional Energy Plan (PER)

PER was approved by the Resolution of the regional Assembly n. 141 of 14th November 2007. The Plan complies with the general objectives of the energy policy of the Regional Law n. 26/04 and with the Community and State fundamental principles. It set the objectives, the tools and the guidelines for the actions to be carried out by Emilia-Romagna Region and the local authorities on its territory with regards to:

- energy spare
- renewable energies promotion
- improvement of the territorial energy performances, especially as far as the buildings, SMEs, mobility, distributed energy systems, agriculture and forest sectors are concerned
- improvement of security, continuity and cheapness of internal delivery
- usability, dissemination and quality of services for the public, especially as far as disadvantage areas and users
- improvement of environmental sustainability of energy supply
- reduction of greenhouse gas emissions

PER stresses the need of creating a context which can support the development of practices based on the principles of environmental and energy sustainability, aimed at the rational energy use and the use of renewable energy sources, together with the increase in the supply of high efficiency cogeneration services. This could provide the opportunity of fully using the produced thermic energy, also through the development of district heating networks for local communities. In this way the territorial planning would comply with the

general objectives of energy sustainability set by LR n 26/04, art. 1, paragraph 3.

During the last years electric power plants based on renewable sources (water, wind, solar and biomasses) have grown in the regional territory. Nevertheless, they do not play a key role yet within the regional electrical balance. Among these plants, also thanks to the promotion politics that have been implemented both at national and regional level, the solar (in terms of number of plants) and the biomass (in terms of power) plants have had the biggest success.

Emilia-Romagna Region is aware of the need further promote renewable energy given that its exploitation contributes to climate change mitigation through the reduction of greenhouse gas emissions, sustainable development, security of supply and the development of a knowledge based industry, economic growth. According to directive COM(2008) 19, Italy's target for share of energy from renewable sources in final consumption of energy to be reached by 2020 is 17%, with an indicative trajectory set out to meet that share. Italy is the third producer of GHG in EU-27. In order to meet the "Kyoto goal", in 2012 Italy must reduce its emissions of 6,5% of 1990 level.

Regional Territorial Plan (PTR)

PTR was approved by Regional assembly resolution n. 276 of 3/2/2010 and it replaces the previous one approved in 1990. The regional law n. 20/2000 conceives it as the instrument to be used for setting the goals and ensuring social development and cohesion, improving regional competitiveness, ensuring social and environmental sources replicability and enhancement. The Plan does not include a list of issues to be ruled, but it sets economic, social, environmental and territorial goals and objectives to be reached.

According to the Plan, reduction of energy consumption can bring new chances not only for energy, plant and building related firms, but also for innovation of products and processes. This can help housing sector improve its quality and security. Emilia Romagna Region is already providing support in this sense through regional norms amendment.

PTR identifies bio-building and energy spare as the sectors where currently innovation mechanisms can be included in order to reach excellence, also at international level. In the framework of new energy politics, firms must play a leading role, both with regards to energy spare and renewable and clean energy production (green economy).

Issues such as environment and climate change are conceived by PTR as extremely relevant as far as connection between global and local dimension of environmental crisis are concerned. Problems exist of environmental quality at local level, such as constant air and noise pollution and the growth of cases of urban heat islands. It is of key importance that PTR sets not only the necessary politics for GHG emissions reduction, but also actions for adapting to climate change aimed at limiting the damages that can incur and to take any related opportunity. As far as urban issues are concerned, the Plan identify urban planning as a priority in order to put in place pilot actions of territorial management aimed at reducing the cases of heat islands. The current trend of setting oneself in low density new urban areas is causing an increase in non-renewable sources consumption and a progressive loss in environmental quality, which have relevant social consequences.

The integrated transports Regional Plan (PRIT) approved in 1998

The plan has undergone a revision work and has been assigned by PTR the role of specifying the infrastructural and mobility arrangements providing coherence within the transports sector.

PRIT cannot directly rule urban mobility, but it can boost and promote good practices which can be integrated with regional politicise on suburban territory. PRIT '98 was not committed to reduce nor localize mobility infrastructures, but to maximize transports effectiveness while reducing its costs and environmental impact.

As far as environment is concerned, during the last years relevant results have been obtained with regards to air-quality. Monitoring figures show that regional and local authorities politics have had a positive impact on the levels of air pollutants. Emilia Romagna Region in committed to continue working on politics against atmospheric pollution, especially in urban centres. Focus will be both on private traffic regulation and enhancement –already ongoing- of incentives to sustainable mobility and improvement of public rail and road transport services.

As far as fundamental measures against pollution are concerned, among the main actions there are the renewal of buses and trains (on railways within regional scope), the improvement of cycle lanes and of sustainable people mobility, the reduction of energy consumption in the production and civil sector, cars' fuel switching into lpg and methane.

Environmental Action Plan

The Plan was approved by the Regional Assembly on 3rd December 2011 and it is aimed to putting in place environmental projects. 150 million Euros have been budgeted for actions on biodiversity, sepa-

rate collection of rubbish and rubbish traceability, water and air quality and sustainable mobility.

Incentives, financing and regulatory actions in support of environmental restoration, energy conservation and reduction of the phenomena related to climate change put in act from your local authorities to facilitate a sustainable land use (local authorities means the communal level)

Regional Law (LR) 20/2000 “General discipline on territory protection and use”
Municipal Operational Plans “POC”
Urban and Buildings Regulation “RUE”
Municipal Structural Plan “PSC”

Regional Law (LR) 20/2000 “General discipline on territory protection and use” puts municipalities in charge of a series of tasks in order to facilitate the sustainable use of territory and keep its changes under control as far as urban transformation issues, social, economical and environmental topics are concerned. These tasks are included in two main instruments. The first one is the **Municipal Structural Plan (PSC)** which acknowledges all prescriptions and orientations set at the national, regional and provincial level and elaborates the politics and objectives aimed ad promoting and im-

proving environmental quality in the framework of territorial management and urban planning. The second one consists of operational instructions for short term transformation and preservation actions, for which the Urban and Buildings Regulation (RUE) provides instructions on the methodology for conducting sustainability and feasibility assessments.

In specific terms, operational contents for urban planning are contained in:

- The **Municipal Operational Plan (POC)** (art. 30 – LR 20/2000): it is the urban instrument that follows the PSC and which sets and regulates protection and renewal actions, territorial management and transformation actions to be put in place in a 5 year period. POC is conceived as a multiannual operational plan, it relies on the municipal multiannual budget and it is an orientation and coordination instrument for the 3 year public works programme and for the other municipal instruments set by national and regional laws.
- **Urban and Buildings Regulation (RUE)** (art. 29 – LR 20/2000): it is the urban instrument that regulates the typologies and methodology of transformation actions, together with the designation of the area for any specific function. The regulation also focuses on: constructions, physical and function transformations, buildings preservation including sanitary and building norms related issues, architecture and urban issues, green areas and other elements which characterize urban areas.
- **Implementation Urban Plans (PUA)** (art. 31 – LR 20/2000): they are detailed urban instruments that regulate new-urbanization and renewal works scheduled in POC.

PSC stresses the importance of actions aimed improving the quality of urban and periurban areas both with green areas and landscape redesign, through trees planting along the borders between city and countryside in order to make landscape more heterogeneous and to protect biodiversity.

PSC orientations also focus on the development and renewal of existing green areas, together with ancient public gardens and those of historical villas. These areas are conceived as urban centres of excellence and can represent the starting point for “green thematic routes” that are further developed by RUE and detailed planning.

Big parks can also play a key role as far as environmental quality and social development of urban areas and outskirts are concerned. Parks are conceived not as equipped free areas, but as locations which can boost social and cultural activities. As a matter of fact, they have become areas providing services and places for spare time and cultural activities. In addition, parks located along the rivers have also the function of an ecological network which connects the different areas within a city.

Finally, green areas acquire a fundamental task in the framework of the transformation processes of urban landscape planned by municipal policies and can have a positive impact on territory and environment.

In the framework of urban planning, wide natural matrices are enhanced through a better definition of the borders between artificial and natural areas and through the creation of wide connection infrastructures (e.g.: main roads and railways).

The work plan that comes out, according to PSC forecasts, presents the following strengths:

- a strategy for managing accesses to urban areas, with a particular focus on tourism, based on intermodality and public transport;
- the improvement of mobility safety conditions;
- the protection and development of pedestrian and cycle mobility;
- public transports promotion and development.

In conclusion, PSCs, following PTR orientations, contribute to reduction of phenomena related to climate change, supporting compact settlements and maintaining the usual dimension of the cities and

villages, avoiding duplication of services, planning an ecological network at municipal level aimed at enhancing existing wide environmental matrices and which serves as connection among areas of key environmental interest.

As far as UHI phenomena are concerned, norms set by municipal authorities and relating to constructions and urban areas transformation are included in RUE and focus on: air and water quality, air and water pollution prevention, water cycle management, reduction of noise and electromagnetic pollution; safeguard of land permeability and ecological rebalancing of urban environment, separate rubbish collection.

It is important to note that the Department for Urban Quality of Emilia Romagna Region has recently set a list of technical requirements on sustainable construction. They are updated according to the most recent guidelines on environmental protection and energy spare and they are currently tested on a voluntary basis by some municipalities, as the regional law does not compel to adopt such norms. Among these requirements, standard I 2 (Urban scale 2) focuses on monitoring sun exposure, because if this is not duly taken into consideration it can concur in causing UHI phenomena.

Implementation of the Directive 2001/42/EC on the assessment of the environmental effects of plans and programmes

Regional Law n. 6 of the year 2009 “Government and renewal of territory”

Regional Law n. 20 of the year 2000 “General discipline on territory protection and use”

Sustainable development is among the priorities of the EU.

At the beginning of the XXI century, the European environmental policy makers must face hard challenges and must especially put in place the decisions of the Amsterdam Treaty concerning the integration of environmental economical and social politics.

In its conclusions of the Helsinki Summit in 1999, the European Council asks to the Commission to prepare a proposal for the Sixth Environmental Action Programme including a long term strategy to integrate sustainable development policies from an economical, social and ecological point of view. The programme “Environment 2010: our future, our choice” was approved in January 2004.

The sixth Programme consists of a short strategic document including the priority actions for environmental politics at European level for the next ten years, with a special focus on the environmental problems.

Following this Programme, the Commission issued the Communication “A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development” (COM 2001, 264) which highlights the integration of environmental protection in all the actions and politics within the environmental field.

According to the EU orientations, the economical objective of competitiveness, the social objective of employment and the improvement of an effective use of resources, must be integrated in a unitary strategy which crosses all the levels of territorial planning, from Provinces to Regions and States. This should also involve firms, consumers, economical institutions, fiscal and monetary authorities

and the whole society because the general consensus is necessary to support sustainable development.

As a matter of fact, sustainable development is the only success strategy to increase competitiveness together with employment and to develop eco-efficient technologies, dematerialisation strategies, environmentally-friendly policies within all economic sectors.

In Emilia-Romagna Region, the concept of sustainable development is of key importance to evaluate and select the policies and actions to be included in the instruments of territorial planning.

The Environmental Evaluation (VAS) was introduced by the Directive 2001/42/CE of 27th June 2001 concerning the assessment of the environmental effects of plans and programmes. This has been followed by the Decision 871/CE of 20th October 2008 on the VAS Protocol.

Italy has regulated VAS through the legislative decree (D. Lgs) n. 152 of 3rd April 2006 “Environmental Norms” which has been replaced by D. Lgs. N.4 of 16th January 2008 “Further corrective and integrative regulations on D. Lgs. n. 152 of 3rd April 2006”. This law focuses on procedural aspects: in order to guarantee a high level protection of environment it does not set limits to be respected, but it establishes that impacts on environment must be taken into consideration during the elaboration of plans and before their approval.

Ahead of European law on VAS, Emilia-Romagna Region has approved in 2000 the law n. 20 “General discipline on land protection and use” which introduced, among other innovations, the “pre-emptive evaluation on environmental and territorial sustainability” (VALSAT) as a constitutive element of approved plans.

After that, Emilia-Romagna Region has acknowledged the legislative decree n 4/2008 with the Regional Law n. 6 of the year 2009 “Government and renewal of territory”.

Regional Law n. 6/2009 has stressed the importance, already expressed in the previous law n. 20/2000, of the sustainable territorial and urban planning introducing the following issues:

- Starting from the initial elaboration phases and until their approval, plans must take into consideration the impacts that their implementation can have on the environment and territory.
- In the annexes of the approved plan, a specific document must be included where potential impacts on environment of the implementation of the plan are identified, described and evaluated. Besides, the necessary actions to avoid, reduce or compensate these effects must be mentioned, taking into consideration the characteristics of the territory and the area.
- In order to avoid any duplications in the evaluation, the results of the higher level plans and of those ones that are intended to be changed.
- The regional and provincial authorities, as competent bodies, express their opinions on the environmental evaluation of, respectively, the provincial and municipal plans.
- The regional, provincial and municipal authorities must also monitor the implementation of their plans and of their effects on the environment and territory, also with the aim of revising or updating them if needed.

In addition, minimum fulfilments are set for the implementation of the environmental evaluation of the plans. Especially, in order to guarantee the transparency of the decisional process, the completeness and reliability of the information used within the evaluation, some obligations are set:

- Both environment related experts and the general public (citizens) must be consulted in the evaluation.
- Detailed explanations on how environmental issues have been taken into consideration during the elaboration of the plan and a monitoring programme during the plan implementation phase must be provided.
- Environmental documents used during the evaluation, the expressed advices and the final decision must be communicated and must be available.

Finally, it is important to mention art. 6 of the Regional Law n. 20/2000 which acknowledges the development of mobility infrastructures –especially railways- as conditions that the plans for the transformation of the territory must comply with. Consequently, the concept is stressed once again that territorial planning must link the works for the development of settlements with the relevant conditions that reduce their impacts and that make them compatible with the contexts where the works are implemented. This also includes interventions to mitigate negative impacts such as the construction of mobility infrastructures and especially the public transports on railways.

ANNEX B

APPENDIX B

TECHNICAL CONTENT OF THE REQUIREMENT ON CONTROL OF SOLAR ENERGY INTAKE

As part of the Emilia Romagna Region's General Directorate Territorial and negotiated planning, agreement,, the Urban Quality Department, has recently prepared a list of technical standards relating to building sustainability.

These standards, updated to the latest guidelines in terms of environmental and energy savings, are currently tested voluntarily by some municipalities in the region.

Regional Administrative Arrangements in fact, does not oblige the adoption of similar rules, but leaves it to each municipality, the autonomy of decision regarding the environmental and urban planning.

The Standard I 2 attached, addresses the issue of controlling exposure to the sun, that if not properly designed, can cause the urban heat islands (UHI).

STANDARD I 2 *(for residential and commercial areas and city neighbourhoods)*

The requirement is part of the Family: Energy Efficiency

Need

Contribute to a rational use of climate resources and energy by controlling access of the sunbeams to the building structures, to the active solar and passive systems and outdoor living spaces through the use of an integrated design approach that controls the solar energy and direct and indirect effects that can generate to outward micro-climate and buildings.

Scope

Uses: for all purposes (residential and commercial buildings, city neighbourhoods)

Performance level

The performance levels are reported separately within the winter and summer sunshine and in compliance with the methodology of integral design; the solutions must meet both conditions.

Summer sunshine

In order to contain the phenomenon of "Urban Heat Island", and the resulting overheating in the summer, it is necessary to simultaneously control the shading and manage a strategic relationship between the paved and built areas and green spaces, their position with reference to constructed and which finishing materials the outer surfaces have been chosen, within those with high reflectance characteristics of solar radiation. The shell of the buildings must be protected from the effects of solar radiation with specific solutions, such as ventilation of the same or with a double ventilated outer covering, green roofs, etc.

The external parking spaces and pedestrian paths, should be properly shaded. An obvious shielding effect is given by trees and vegetation. It's important to choose the essences in terms of their form and content of their character but also of their cast shadow. The beneficial effect of shading is more significant if the trees provide shade in the heated season, especially for deciduous plants that do not interfere with the winter sunshine. The use of green roofs is an excellent solution to reduce the load on summer thermal cover and to limit the "heat island phenomenon" in a neighbourhood next to the intervention. And through the appropriate placement of plants, the local microclimate can be optimized by choosing the type of paved surfaces. The surfaces with which the user can come into contact have to submit poor attitude to overheating, through a feature of high reflectance of solar radiation and emissions.

Winter sunshine.

The only access to the building structures and outdoor spaces (in particular the stopping places) must be carefully controlled in relation to any external obstructions.

If there are areas devoted to active or passive solar house systems is required to control the sun exposure of the same. It is required that is guaranteed exposure to the sun more than 80% occurred at 12 pm on December 21.

Method of verification at the design stage.

Technical report which explains the design process carried out ,with reference to the performance specifications as above and giving reasons for decisions taken.

This report will demonstrate the control design through the use of daylight control tools (for instance: solar axonometry) to analyze

and document the effect of strategies on the control of energy intake on the aggregation of buildings and on outdoor spaces.

To control the effects of shading is to analyze the shielding (artificial plants or mixed) that restrict access of direct solar radiation on the outdoor areas of the site and on the fronts of buildings and roofs of the various projects.

The distance between the buildings or the placement of other obstructions induced by the intervention should be calculated on the basis of the above effects.

The verification tools with daylight control is mandatory in the case are provided for passive and active solar systems, the 'solar access" must be assessed in places (roofs, roofs, etc. ...) in which it is expected they will be installed. This verification will be aimed to the definite project of every single building of the area.

Method of verification at work completed

Declaration of conformity of the work carried out with respect to the project.

ANNEX C

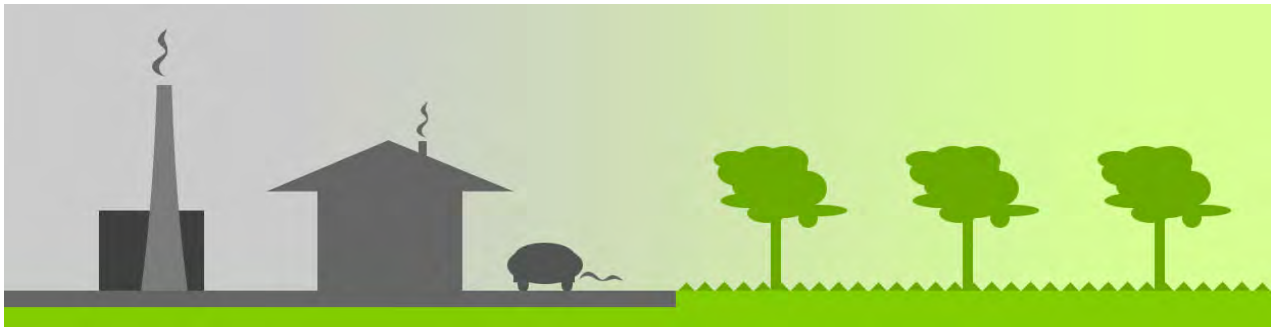
POC MOW

**URBAN UPGRADING OPERATING PLAN FOR THE WEST MODENA
DISTRICT**

ARTISAN VILLAGE

GUIDELINES

FEASIBILITY STUDY OF ENVIRONMENTAL QUALITY INDEXES TO BE APPLIED TO BUILDING LOTS



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TABLE OF CONTENTS

1.

INTRODUCTION..... 234

2.

EXISTING ENVIRONMENTAL QUALITY URBAN INDEXES.. 236

3.

DESIGN OF EXPERIMENTAL ENVIRONMENTAL QUALITY INDEXES 242

3.1 PRODUCT CHARACTERISTICS244

3.2 TYPES OF ACTIONS.....245

3.3 DATA ENTRY (ACTUAL STATE - PLANNED STATE)249

4.

“RATE” INDEX (reduction in the absorption of thermal energy) 252

4.1 PHENOMENA ANALYSIS METHODOLOGY253

4.2 SIMULATION OF PLANTS.....255

4.3 INDEX OUTPUT.....255

5.

“HYPER” INDEX (HYDRAULIC’S PERMEABILITY AND ELEMENTS OF RETENTION) 257

5.1 INDEX OUTPUT.....258

6.

INDEXES AS GUIDELINES FOR THE PLANNING PHASE..... 260

6.1 INDEXES AND ECONOMIC ASSESSMENT OF PLANNING SOLUTIONS 260

7.

FURTHER GUIDELINES SUPPORTING THE PLANNING PHASE 262

8.

INCENTIVES, BONUSES AND AWARDS 264

8.1 LIMITS TO THE GRANTING OF BONUSES AND AWARDS 266

9.

REFERENCES..... 267

1

INTRODUCTION

On the main goals of the Artisan Village Upgrade Plan is to renew the buildings in the Village, by means of a deep restructuring of the existing edifices, respecting the size and volume relations among them and producing a new estate body, which carries on and updates the typical evolution process of the Artisan Village.

Taking into consideration the modified environmental conditions of the area, the Plan aims to promote measures envisaging high-level performances, in order to ensure the environmental as well as the urban upgrade of the area.

The Plan may envisage the granting of awards in case of upgrade actions which can guarantee such quality levels as to enhance the environmental value of the structures and the recognizability of the urban context. In this respect, the devised plan envisages the implementation of a procedure ("BAF", see below) for assessing the improvements achieved during the planning phase.

Later, some in-depth analyses were carried out on this index and similar indexes (described below), in order to be sure about the best tool to include in the award attribution Plan.

At the same time, we started to consider what the main environmental issues to work on could be, by means of building procedures. In this phase, a role of the utmost importance was played by the introduction of the Plan among the "pilot cases" of the "UHI" European project, which aimed both to analyse the phenomenon of urban heat islands and the prepare decision-making support tools in order to overcome this phenomenon.

As these issues were studied more and more in depth, we realized that each urban index analysed had certain peculiarities, which could meet specific requirements of the Plan, but at the same time specific issues came up which would limit their applicability.

The more in depth the approaches implemented by the various administration were studied, the more we could outline the main environmental issues to take into consideration in the planning of a building lot and, therefore, what behaviours were to be promoted in order to reduce the building impact. This has also made it possible to define the main characteristics to include in the Plan guidelines, then it was decided to try to develop a new index, an experimental one within the framework of the Plan, to be used both as a synthesis of the guidelines and as an assessment tool. Later, the single environmental issues were analysed, in collaboration with experts from the administrative bodies (Hydraulic Works office, Environmental Sector of the Municipality) and well known professionals (EELab Department, University of Modena). Also due to some further contributions given by the various experts involved in the UHI project (external professionals or bodies, such as the Province and ARPA), and a comparison with the other European subjects involved, a first validation of this approach was reached.

This report summarises the main features of the environmental method prepared by the administration. It is worth stressing that there are various analyses still under way for the final validation of various technical and procedural issues; as a consequence, although the structural characteristics have already been defined, the approach implemented may still be modified or emended.

2

EXISTING ENVIRONMENTAL QUALITY URBAN INDEXES

In order to devise a method for assessing the "environmental" performances of a building lot, several towns in Italy, in Europe and worldwide have included standardized procedures ("urban indexes" in their building regulations, in order to calculate the general impacts of town-planning activities.

In general, for calculating the indexes, it is necessary to know the types of materials/actions present in the building lot and the area they cover (m_2). By applying different "weights" to every material/action, a value is obtained, proportional to its "environmental quality", through the use of simple calculation algorithms. These values make it possible to obtain a number, which expresses the overall characteristics of a specific building lot. In order to ensure a suitable performance level, it is generally necessary to plan an activity in such a way as to get an index not lower than a certain threshold.

The common characteristics of the indexes is to provide a relatively simple and clear calculation methodology, aiming to plan building areas without any fixed schemes, since it is based on the achievement of minimum performance levels, which let you free to choose the various materials/actions to apply within a batch.

BIOTOPE AREA FACTOR (BAF) INDEX – BERLIN

As early as in 1990¹, the city of Berlin adopted an index called Biotope Area Factor (BAF), in order to reduce the impacts already present in the town centre and to facilitate an ecological upgrade of the urban context. The BAF is the ratio between ecologically "effective" surfaces and the total area of the land.

From a qualitative point of view, the index aims to safeguard the microclimate, to control the use of the land and water, to improve the quality of plants and the habitat for animals, to improve the vital space for human beings by means of the creation of yards with green areas (or areas with a certain permeability, such as self-blocking ground or gravel), green roofs, green walls or by means of infiltration of rain water to surfaces with extended vegetation.

From a quantitative point of view, it provides a value between 0 and 1 and represents the part of the area for plants and other functions of the ecosystem. The higher the value, the better the result obtained in the building lot planning.

The index applies to residential, commercial and infrastructural areas (whether existing or newly

¹ "The Biotope Area Factor as an Ecological Parameter" – Berlin, 1990.

made): depending on the various actions to implement, minimum values of the index are set, in a range from a minimum of 0.30 to a maximum of 0.60.

GREEN SPACE FACTOR INDEX (GSF) – MALMÖ

This index was designed in 2001, partially drawing inspiration from the BAF in Berlin.

From a qualitative point of view, the index aims to measure the ecological value of a settlement, on the basis of the presence of vegetation and permeable areas. The index takes into consideration the types of surfaces envisaged by the BAF (yards with green areas or in any case permeable areas, green roofs or green walls) and integrates them with water surfaces or rainwater collection systems, quantifying the contributions of trees and bushes and promoting urban agriculture. As regards the quantity, it provides a value between 0 and 1. The minimum value to reach is 0.6.

What is peculiar in Malmö's approach is the requirement, on the part of planners, to implement the verification of the GSF index by envisaging a certain number of measures, called Green Points, which are pre-determined for certain types of biotopes, animal habitats or urban agriculture².

Malmö, along with some other European organizations, belongs to the Grabs project (Green and Blue Space Adaptation for Urban Areas and Eco Towns), aiming to integrate strategies to adjust to climate changes within the framework of regional planning tools³.

GREEN FACTOR INDEX - SEATTLE

On the basis of the experience achieved in Berlin and Malmö, Seattle also designed its own index in 2006. Initially, it was only applied to commercial areas, later it was extended to residential areas. From a qualitative point of view, this index aims to increase the aesthetics of buildings, to increase permeability, to improve energy efficiency of buildings and to reduce the urban heat island.

It uses the same action categories envisaged by the BAF (yards with green areas or permeable areas, green roofs or green walls) and those added by the GSF (rainwater collection, trees and bushes, urban agriculture), enlarging them by means of in-depth technical details. From a quantitative point of view, it is absolutely similar to the BAF, although it has a much more specific approach (the administration provides a spreadsheet for processing the index).

The peculiarity of the Green Factor is to carry out a cost analysis relative to each single action, in order to simplify the cost/benefit estimate, and it attributes bonuses for certain actions, such as improving the landscape publicly visible.

Seattle was the first American city to apply an index of this type, later it has served as a model for other cities, such as Bellingham, Portland, Chicago, DC, Bewark (etc.).

² Grabs Expert Paper 6 - The Green Space Factor and the Green Points System – 2011.

³ The project involves the following countries: Austria, Greece, Italy (Genoa, Catania), Lithuania, Netherlands, Slovakia, Sweden, United Kingdom.

BUILDING IMPACT REDUCTION INDEX (RIE) - BOLZANO

Since 2004, the Municipality of Bolzano has been applying a Building Impact Reduction index (RIE), which defines the ratio between green areas and non-green areas, within the framework of its Building Regulations. The index applies to all newly built elements and on actions involving existing buildings, as well as actions which involve external surfaces exposed to rainwater. From a qualitative point of view, the index aims to reorder rainwater and lower urban temperatures. The index is mostly based on permeability of materials, assessing the presence of green surfaces (agricultural, non-agricultural or for sports facilities), trees, water bodies, partially permeable grounds and green roofs. From a quantitative point of view, the calculation algorithm is slightly more complex than the one used for the previous indexes, and results in a value between 0 and 11 (approximately⁴, the administration provides a spreadsheet for calculating the index). The higher the value, the better the result obtained in the building lot planning. Depending on the various actions to implement, minimum values of the index are set between a minimum of 1.5 to a maximum of 4.0.

What is peculiar in the RIE is the technical analysis of various types of green hanging covers on roofs (synthetically: intensive and extensive).

BUILDING IMPACT REDUCTION INDEX (RIE) - BOLOGNA

Since 2009, the Municipality of Bologna has also been applying the RIE index in its Building Regulations. The index applies to both existing buildings and newly constructed ones, excluding those with a ratio between building lot and land area higher than 0.5. The algorithm used is fundamentally identical to that of Bolzano (the administration provides a spreadsheet for calculating the index).

Although it implements a coefficient which takes into consideration the pith of non-green areas, the spreadsheet provided for the calculation is designed in such a way as to attribute a single conventional value to the pith of all surfaces.

The peculiarity of the approach of Bologna is the presence of improvement performance levels aiming to promote building actions such as to enable an improvement of sustainability of the buildings: in addition to basic performances, identical to those defined by the RIE of Bolzano (minimum values of the index ranging between 1.5 and 4.0), "improvement" performance level (index minimum value between 2 and 5) and "excellence" ones (index minimum value between 2.5 and 6) are also envisaged, associated with certain incentives.

⁴ "Manuale d'uso del foglio di lavoro Excel per il calcolo del RIE" – Comune di Bolzano – Ufficio Tutela dei Beni Ambientali.

OTHER ITALIAN EXPERIENCES

Several towns in Italy have implemented various tools aiming to enhance the environmental value of buildings. In particular, the experiences of Brescia, Florence and Rimini are explained below.

What is different in the approaches of these administrations is the application of incentives which may result in lower taxes (economic incentives) or in the adjustment of town-planning parameters by means of correction coefficients (procedural incentives).

The **Municipality of Brescia**, in the building regulations of 2008 (guidelines, chapter called "Nature") dealt with the use of green walls, introducing minimum quantitative parameters depending on the possibility of receiving a series of benefits (both procedural and economic).

The **Municipality of Florence**, in the 2007 building regulations, included a series of indications on the use of green areas, promoting the implementation of measures aiming to "decrease the heat island effect" (by controlling the pith of the ground, the use of urban green areas, designing proper positions for summer shades and the planting of trees and bushes).

The incentives envisaged are both economic and town-planning in nature, they apply to actions on new structures, newly-built edifices, urban restructuring actions and building restructuring (percent reduction of concession expenses and application of adjustments which take into consideration the increased extent on the S.U.L.).

The **Municipality of Rimini**, in 2006, introduced a series of incentives for the sustainability of new actions and restructuring works in its building regulations. This document calls them "Biobuilding actions", and they introduce the issue of the use of green on façades and in covers. In the chapter "Quality of life", under the entries "Urban quality" and "Architectural quality", green actions which benefit from incentives are listed (for instance, a reduction of up to 50% of secondary urbanization charges).

These procedures are a concrete approach which has been taken into consideration in the planning of buildings for years, promoting their environmental sustainability. In particular, the indexes or procedures designed by these administrations highlight the issues which may affect the environmental quality most: the implementation of actions which enhance the quality of buildings and the application of procedures which promote their completion.

Briefly, the favourable features of the indexes or procedures analysed so far are the following.

ACTIONS:

- Building of green areas, namely yards with green areas, green roofs (RIE) or green walls (BAF, GSF, GF).
- Building of permeable grounds (BAF, GSF, GF, RIE).
- Planting of trees and bushes (GSF, GF, RIE).
- Reuse/collection of rainwater (BAF, GSF, GF, RIE).

PROCEDURES: